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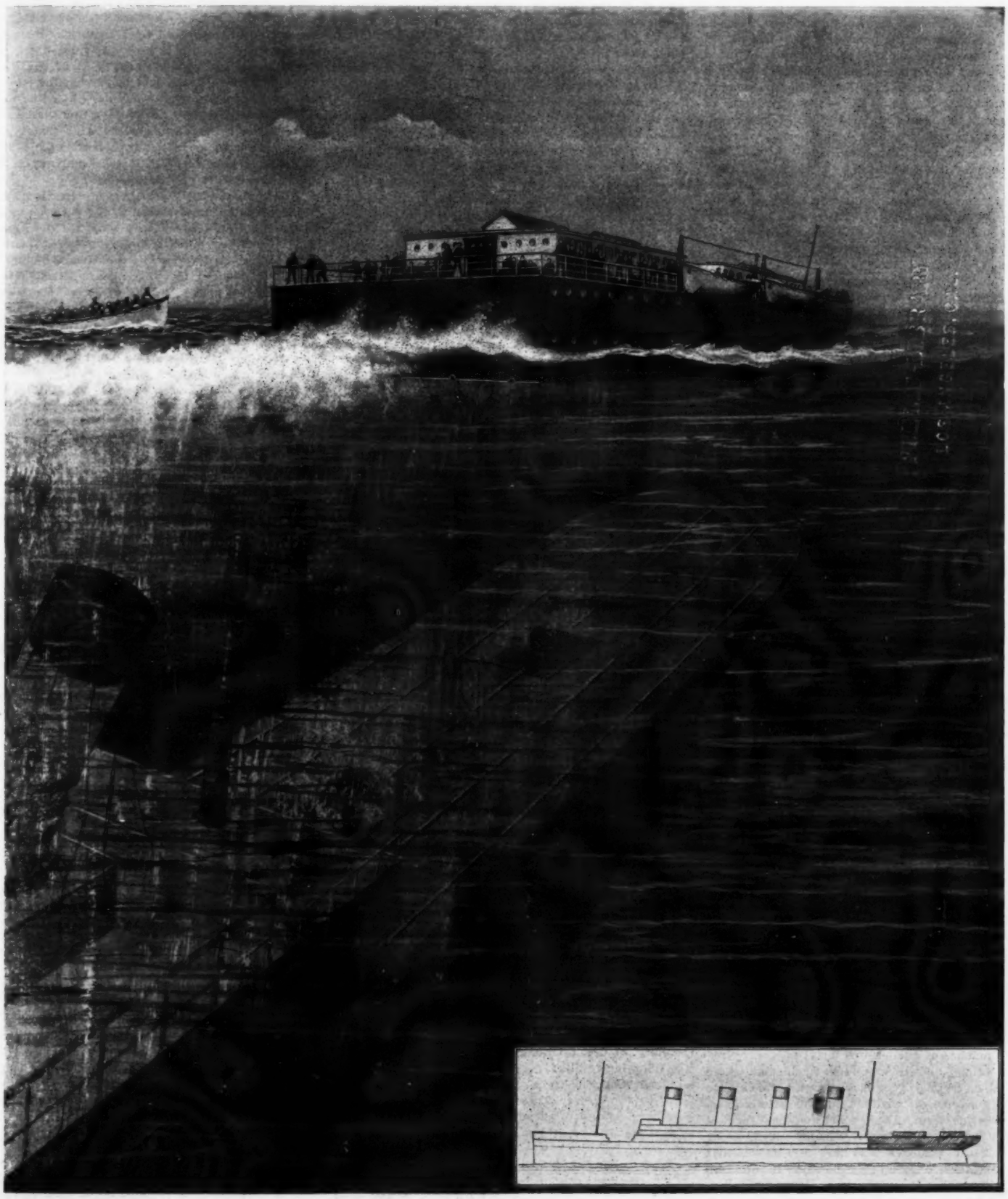

The upper decks of the after-portion of a vessel afloat after the ship of which they were a part has sunk: a suggested pontoon method of saving life at sea.

SAFETY AT SEA.—[See page 12.]

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On Metallic Colloids and Their Bactericidal Properties*

The History of Collosols

By Henry Crookes

MAN is always fighting against unseen foes. In the mediæval ages a question was often discussed, viz., "How many angels can stand on the point of a needle?" If instead of angels we say "devils" or "microbes"—and devils are only angels of opposite polarity—the subject can be brought more clearly to our every-day comprehension. Microbes of disease are the "devils" that medical science is always warring against; they are so small as to be invisible to the naked eye, and, in fact, can only be seen under a high-power microscope—about 1,000 can be placed on the point of a very fine needle. Modern science has, in spite of their minuteness, found them, identified them, photographed, isolated, cultivated, and finally devised means of killing them. The simplest method of killing microbes is by the application of heat; sunlight has also been found to be a very efficient sterilizing agent. Various disinfectants, such as carbolic acid, chloride of lime, permanganate of potash, etc., have been proved to be deadly to microbes. Unfortunately for us human beings, nearly every efficient germicide known until recently has an irritating or destructive action on living organic tissues. The dream of the doctor has been to find an agent that will kill disease, or, in other words, bacteria, and will at the same time do no harm to the tissues of the human body. Immediately following the discovery of radium it was found that the emanations from that wonderful element had a very strong germicidal action, but almost at the same time it was noticed that a very serious burning effect on the skin and flesh was also produced.

In June, 1903, I exhibited at the Royal Society a number of plate cultures and photographs, illustrating the germicidal action of radium emanations on several forms of microbes. The radium rays undoubtedly kill the microbes, but at the same time, unless administered with the most scrupulous care, they also kill, or *burn up*, the living tissues of the body.

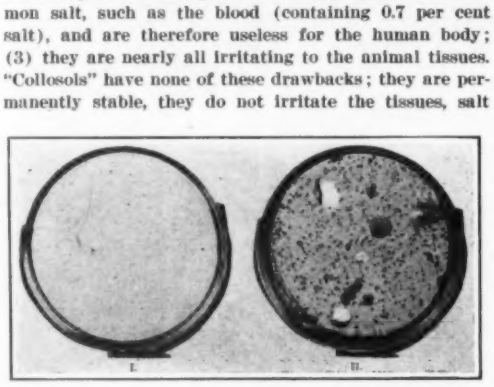
The radium emanations are due to the breaking down of the atom of radium, and electrons are constantly flying off with about two thirds the speed of light (182,000 miles per second). These electrons are now looked upon as being absolute units of negative electricity. To try and illustrate their size is difficult; imagine one drop of water magnified to the size of the earth (8,000 miles diameter); an atom would then be about the size of a walnut or a cricket-ball. Now magnify the cricket-ball or atom to a cube of about 100 feet each side; the electron would be about the size of this dot (.) (1/100th of 1 inch diameter). The mind cannot conceive such figures.

About that time (1903), or shortly afterward, the attention of medical men was directed in a critical scientific manner, apart from tradition and empiricism, to the curative effect of certain waters from mineral springs. Laborious research on the part of many workers has revealed the fact that these curative waters contain a number of extremely small metallic particles, endowed with continuous, rapid, oscillatory movement known as the "Brownian movement."

This condition under which these particles are present is known as the "colloidal" condition. The word "colloidal" is really a misnomer, but it has gained currency by long use. The actual state in which these particles exist is that of extreme minuteness; they remain in suspension, being kept up by the continuous molecular bombardment of the surrounding liquid. Natural waters contain these metallic particles in comparative small numbers, and the problem arose how to increase the number and thus the efficiency of these particles in a solution. One method, known as Bredig's method, of effecting this result was by using a high-tension disruptive electric spark under water, between poles of the metal to be dealt with. Solutions containing an almost incredible number of particles of metal were prepared by these means, and it was soon found that these liquids had a very high germicidal power. After a time it gradually became evident that these electric colloids, as the solutions were called, could not be depended upon; they were not stable and were broken down by the presence of electrolytes. The next problem was that of stabilizing these colloidal solutions. As the workers increased in number the proposed methods multiplied. Organic compounds of metals were introduced, but all had drawbacks, such as non-stability, irritation, caustic effect, etc.

A few years later, during a research I was engaged in, I noticed a peculiar action of some metals in inhibiting the growth of bacteria in their neighborhood; as a result of further work in following up this question I exhibited a number of living cultures and photographs of my experiments at the Royal Society and at the Royal Institution in May and June, 1911. The germicidal action of metals in these experiments is, at first sight, very similar to the observed germicidal action of radium, but with this enormous and important difference, that whereas radium kills and destroys the flesh as well as the bacteria, the other metals (in what is now called the colloidal state) kill the bacteria only, and exercise a bland and soothing effect on the animal tissues.

After further work on the subject, entailing about 2,000 experiments, I was able to produce a harmless liquid containing metallic particles in suspension, endowed with the above-described "Brownian" movement. I have called these preparations "Collosols." The germicidal action of colloid metals in suspension has been known for some time, especially during the last seven or eight years, in connection with medical and therapeutic work; but the great drawback in all previous preparations of this character, as has already been pointed out, is that—(1) they are not stable by themselves; (2) they break down instantly when introduced into a liquid containing even a small proportion of common salt, such as the blood (containing 0.7 per cent salt), and are therefore useless for the human body; (3) they are nearly all irritating to the animal tissues. "Collosols" have none of these drawbacks; they are permanently stable, they do not irritate the tissues, salt



I. II.

Photographs illustrating the preservative effects of "Collosol Argentum."

Two plates of nutrient gelatin exposed on the window-sill for half an hour. No. I had been covered previously with "Collosol Argentum" for five minutes; No. II was untreated; both plates were incubated for forty-eight hours at 20 deg. Cent. No. I is sterile, No. II contains about 350 microbes.

does not break them down, and they contain so small a proportion of metal, viz., 1 in 2,000, that even a poisonous body like arsenic can be used with impunity. Well-known medical men have stated confidently that the dose is unlimited, as only the bacteria and ferments are killed.

Collosols can be applied topically as a lotion, by intramuscular or intravenous injections, or by the mouth, and from numerous trials made by a large number of medical men, as well as from very many laboratory experiments, it has been proved conclusively that there is no microbe that can withstand the action of collosols, when properly applied, for more than a few minutes.

Silver and mercury "Collosols" of the normal strength (1 in 2,000) were diluted with nine times the quantity of nutrient broth (1 in 20,000), and 10 cubic centimeters of this mixture were infected with two loopfuls of a vigorous culture of *B. coli communis;* after shaking, so as to mix thoroughly, streak cultures were made quickly on agar plates, the first within 10 seconds, then at 2, 4, 6, 8, and 10-minute intervals. These plates were incubated at 37 deg. Cent. for forty-eight hours, and gave the following results:

Silver "Collosol" (1 in 20,000) with *B. coli communis:*

After 10 seconds—Growth.
" 2 minutes "
" 4 " "
" 6 " No growth.
" 8 " "
" 10 " "

Mercury "Collosol" (1 in 20,000) with *B. coli communis:*

After 10 seconds—Growth.
" 2 minutes—No growth.
" 4 " "
" 6 " "
" 8 " "
" 10 " FEB 16 1915

(In each case the blank or control streak gave a vigorous growth.)

These experiments were repeated with silver and mercury "Collosols" at the normal strength of 1 part in 2,000. In every case *B. coli communis was killed within ten seconds*, the only growth on the agar plates being those of the untreated control streaks. Several comparative tests were made with the *gonococcus* grown on agar plates smeared with fresh blood, with the usual precautions. A plate showing a vigorous growth and answering to the typical tests (that is, Gram-negative, no growth on gelatin or agar at 20 deg. Cent. without fresh blood, but vigorous growth at 37 deg. Cent. on agar with fresh blood, and displaying the well-known *diplococcus* in pus cells) was swamped with "Collosol" silver for two minutes, after which time streak cultures were taken and transplanted to agar plates smeared with fresh blood as before, at intervals of 2, 4, 6, 8, and 10 minutes, and incubated in the usual way at 37 deg. Cent. *Result—No growth whatever.*

I have carried out many series of experiments similar to this; for instance, with a young vigorous growth of *B. tuberculosis*, I found that with "Collosol" silver (1 in 2,000) it was killed in four minutes. With *Staphylococcus pyogenes*, various *Streptococci*, and other pathogenic organisms, I find that all are killed in three or four minutes; in fact, *I know of no microbe that is not killed in laboratory experiments in six minutes.*

It will be argued that laboratory experiments are not of much value, because of the very different conditions in which bacteria exist in the human body; the answer to this objection is that with a safe bactericide, such as Collosols, of which the dose is unlimited, large quantities, such as one pint or more, can be injected intravenously (this has been done thousands of times with other liquids), and it is well known that a fluid injected into the body soon spreads throughout the whole system. In some circumstances it is desirable and even important to apply colloid metals, not only internally but locally, such as in the case of a diseased joint containing incapsulated bacteria (such as the *gonococcus* or *B. tuberculosis*). I have shown that this can be done by means of a very small electric current of about 30 to 40 milliamperes with an E. M. F. of about 50 volts.

Two blocks of solid nutrient gelatin were prepared, 2 inches diameter and 1 inch thick. A current of 35 milliamperes was passed through one of these *A* by means of silver pole plates 1½ inches square, covered with flannel soaked in silver collosol; the current, obtained from a medical battery of 24 dry cells, was kept on for 20 minutes, the negative pole being placed on the top. The other block *B* was arranged in exactly the same manner, and left for 20 minutes, but no current was passed. Stab cultures of *B. coli communis* were made vertically through the center of each block. Three days afterward I noticed a growth along the line of the stabs, and in order to examine these more closely I made a vertical section of each block close to the stab. I then observed that in block *B* without current there was a vigorous growth of *B. coli* throughout the length of the stab, right up to the surface; whereas, in block *A* with current, there was no growth at the surface, nor for the top eighth of an inch, and below that only a feeble growth for the rest of the line of stab. This proves that the negative current of 35 milliamperes had driven the colloidal particles of silver into the gelatin, where they were able to continue their germicidal activity, and that the particles did not soak into the gelatin to any appreciable extent, without the driving action of the electric current.

To show that medical electric currents do not break down collosols, I passed a current of 40 milliamperes from the same 24 cells through 10 ounces of Collosol Argentum contained in a glass vessel for one hour. The same silver pole plates 1½ inches square were used, and were kept about 2 inches apart. After turning off the current the collosol was examined under the ultramicroscope, and it was observed that no change in the "Brownian" movement had taken place.

Much has been said as to the theory of this killing action. How is it brought about? With regard to the radium emanations it is undoubtedly akin to burning: radium sores are in a way similar to burns but take very much longer to heal. Ultra-violet light, even at the temperature of liquid air (—181 deg. Cent.) has apparently a disruptive or bursting action.

It seems probable that the action of colloid metallic particles in killing bacteria is due to another cause. Assuming, as seems reasonable, and as has been defi-

1913 GRAM

* Paper read before the Royal Society of Medicine, April 8th, 1914, and published in the *Chemical News.*

nitely stated by some writers, that each metallic colloidal particle carries a charge of electricity, these particles in any definite preparation are all electrified in the same manner—negative, for example, in the case of silver—and are therefore mutually repelled, so that in spite of their constant and exceedingly active movement (about 6,000 times their own diameter per second), they do not and cannot touch each other, and thus do not lose their charge. If, however, a foreign neutral body (such as a microbe) enters the solution, these electrified particles are not repelled from it automatically, but may even be attracted to it if it happens to carry a charge of the opposite polarity by the action of absorption; in any case, being of much greater mass, the microbe will receive the charges of many thousands or millions of particles of metal, and this may very conceivably account for its death.

Bacteria are measured under the microscope in terms of μ (1/1,000th of a millimeter), and the average size of a coccus may be taken as 1 μ diameter, or in the case of bacilli 1 μ in length. The size of colloidal metallic particles is, however, very much smaller, and they are measured in terms of $\mu\mu$ (1/1,000,000 of a millimeter). According to Zsigmondy, particles of more than 60 or 70 $\mu\mu$ in a liquid sink to the bottom, while those of less than 3 or 4 $\mu\mu$ cannot be seen under the ultramicroscope, even with bright sunlight as the illuminant. Thus the proportionate size of a microbe and the smallest visible metallic colloid particle is about 330:1, or to give a popular example, their relative sizes are as the elephant in the Natural History Museum compared with the shrew mouse underneath.

The number of colloidal particles in a liquid containing 0.05 gramme of gold per liter, or 0.005 per cent, is, according to Zsigmondy, 1,000,000,000 per cubic millimeter; assuming each particle to be 15 $\mu\mu$ diameter, owing to the difference in specific gravity, there would be about double the number of particles of silver. As Collosol Argentum contains 0.05 per cent—or ten times the amount of Zsigmondy's typical solution—the number of particles present would be, in round numbers—

1,000,000,000 × 2 × 10 × 1,000 per cubic centimeter = 20,000,000,000,000 per cubic centimeter of 15 drops.

An illustration of the protective value of "Collosols" is shown in two photographs (Figs. 1 and 2). Two plates of nutrient gelatin peptone, *A* and *B*, were exposed on the window-sill for half an hour. *A* had been previously washed with Collosol Argentum, *B* was untreated. Both plates were then placed in the incubator at 20 deg. Cent. for 48 hours. It will be seen that *A* is sterile, while *B* contains about 350 colonies of microbes. It must be admitted that about an equal number of bacteria in the dust will have fallen on the two plates during the time of exposure side by side; the result shows the *rôle* of colloidal metals in the form of "Collosols" as a protective agent in dressing wounds after operations, and also all smaller scratches, wounds, and sores on the body.

With reference to the medical employment of these preparations, my medical and other friends have, during the past two and one half years, furnished me with very encouraging reports, which seem to warrant these remedies receiving a more extended trial by the medical profession. It is to be hoped that they will receive the attention which they deserve.

Identity of Chemical and Biochemical Laws

THE average educated man of the present age probably believes that, while it has long since become impossible to draw a demarkation line between organic and inorganic compounds, the general laws of chemistry cannot be applied to the physiological problems affecting living organisms. The argument that vital force is not mechanical or chemical force, is considered sufficient to terminate any discussion of attempts to solve the problem as to the origin of life on general scientific lines. Hundreds of organic compounds have been prepared synthetically from substances which can themselves be built up in the laboratory from the chemical elements. But it is rightly objected that the methods applied differ radically from those with which Nature works. If a particular organic substance can be produced in the laboratory by submitting other compounds to the action of strong acids and to high temperatures and pressures, that form of synthesis certainly does not tell us anything as to the way in which the plant assimilated its food and prepared that particular substance. It would be wrong to claim any analogy in such instance. But we know now, for instance, that the abstraction of the carbon dioxide from the air, and the restoration of oxygen to the air, can be effected by ultra-violet light, without the intervention of plant chlorophyl, hitherto deemed indispensable, and experimental science seems to have sufficiently advanced to assert that the general laws of chemistry and biochemistry are identical, instead of being opposed to one another.

To prove this was the aim which Prof. Svante Arrhenius, Director of the Nobel Institute of Physical Chemistry at Stockholm, had set himself in delivering three Tyndall lectures on "Identity of Laws in General and Biological Chemistry," at the Royal Institution, on the three Thursdays before Whitsuntide. Prof. Arrhenius has himself chiefly investigated this field of late. We cannot follow him into the details of those researches; but we will refer to the chief results. He showed in the first lecture that certain chemical reactions had been observed which seemed to be incompatible with the laws of general chemistry, but which had their analogies in biochemistry. The difficulties in the latter cases were therefore not characteristic of vital processes, as had been assumed, and the chemical study threw light on the biochemical processes, and *vice versa*. In the coagulation of proteins and in the decay of organic substances, for instance, the catalytic effects mainly depended upon the presence of hydrogen or of hydroxyl ions, and this again depended upon the presence of small traces of acids or bases. The acidity changed during the progress of the decay, the character of the digestion (by means of pepsin) changed with it, so that the digestion did not proceed proportionally to the time, but proportionally to the square root of the time, just as in the analogous chemical case of the action of ammonia on ethyl acetate; the products of this reaction were ammonium acetate and alcohol. The peculiar deviation from the general laws in the inversion of cane-sugar by the aid of invertase (the yeast enzyme) was a similar case.

These digestion experiments, etc., had been made *in vitro*, in glass vessels. In the living body the reactions were more complicated, but they followed the same laws. That had been proved from the inversion of cane-sugar by living yeast-cells and by digestion experiments with dogs, studied especially in St. Petersburg by Pawlow and his pupils. We confess that we were much more struck by the general regularity and similarity of the digestion curves than by certain irregularities to which Prof. Arrhenius directed attention; considering that as many as forty fistulæ were placed in the alimentary ducts of the same dog, one could only wonder that normal results were obtained at all. But the fermentation of milk by rennet, the destruction of bacteria—studied especially in London by Martin and Miss Chick—followed again the same laws, and the influence of a temperature rise of a few degrees was as remarkable as in many chemical experiments. Even the possibility of the synthetical building up of organic substances by the aid of enzymes had finally been demonstrated, Prof. Arrhenius explained in the third lecture. Enzymes, as a rule, broke up complex compounds into compounds of simpler constitution. In 1898, Van't Hoff had predicted that it should be possible to build the original substance up again by the action on the decomposition products of the same enzymes which had effected the decomposition; the confirmation of this prediction had long been delayed, but had been realized quite recently. When casein was decomposed by pepsin, e. g., and the pepsin afterward allowed to act on the resulting albumoses, a protein substance had indeed been obtained, but it was not the original casein; the success had therefore only been partial so far.

Again, the lecturer continued, the equilibrium laws concerning the partition of a substance between the different solvents or substances with which it could react were not different for general chemistry and for biochemistry. It had, for instance, long been known that blood corpuscles took up a very much larger proportion of certain salts or poisons than the blood serum; but similar enormous differences were observed when different salts were brought into mixtures of acetone and alcohol, for instance. Thus the blood corpuscles took up 450 times as much silver nitrate, 590 times as much acetic acid, 750 times as much caustic soda, and more than 2,000 times as much mercuric chloride (one of the most deadly poisons) as the so-called physiological salt solution (0.9 per cent solution of sodium chloride in water) did. These researches had a very important bearing on the action of poisons, on the one hand, and on the immunization against bacterial or other poisons, on the other. The diphtheria poison, or toxin, was neutralized in the system by the antitoxin injected, just as a base was neutralized by an acid. The peculiar phenomena of hæmolysis and precipitations (injecting the blood of one animal into another), even the peculiar immunity phenomena connected with the names of Ehrlich and of Danysz, had their parallels in ordinary chemistry; the growth and decline of a fever gave the same curve as the growth and decline of the respective bacteria; and both the active immunity (secured by the injection of an anti-toxin) and the passive immunity (by injection of a weak culture of the same bacterium, as in vaccination against small-pox and against rabies) could be accounted for on general lines. Though, therefore, science remains far removed from the possibility of explaining vital phenomena, Prof. Arrhenius was able to make out a good case for his claims as to the identity of the laws of general chemistry and of biochemistry.—*Engineering.*

Man and the Mammoth in America*

By George Frederick Wright

THE recent discovery of a well-preserved skeleton of *Mammoth americanum* in Farmington, Conn., gives new interest to the question of the coexistence of man with the mammoth in America, and to the further question of the dates of the extinction of the mammoth and of the close of the Glacial period. The discovery was made late in August, 1913, by some Italian workmen who were digging a trench on the estate of Mrs. A. A. Pope. The workmen on striking the skull thought at first that it was a tree trunk, and hence injured it somewhat. On discovering their mistake they reported it to Mrs. Pope as a "black devil." Mrs. Pope promptly brought it to the attention of Mr. Charles Schuchert of the Peabody Museum of Yale University, who has given an account of the discovery in the April number of the *American Journal of Science.*

The bones were nearly all together in the place where the animal died, but one of the tusks was 23 feet away and on ground which was 2 feet higher than the rest of the skeleton. Though the animal was not full grown, the skeleton when mounted will stand about 8 feet 2 inches at the shoulder, with a length of 13 feet 2 inches from the tip of the premaxillary bone to the curve of the tail.

Special interest in this discovery is aroused by the evidence it gives of the recent extinction of the mammoth in North America, and of its being a contemporary here with man. Evidently the animal under consideration was entombed shortly after the vanishing of the ice sheet from the highlands of Connecticut; for the skeleton was found in a shallow trough (or kettle hole) on the surface of the "till," or direct glacial deposit. As no organic matter or oxidized till was found beneath the skeleton, and as very little vegetal matter is seen in the boulderless clay surrounding the bones, it is evident that the entombment occurred shortly after the ice had withdrawn, and before much vegetation had spread over the glaciated surface. The animal was buried by 4 feet of clay, over which 18 inches of turf had accumulated. Dr. Schuchert estimates that the clay could have accumulated "in a few hundred years, and that the stingy turf apparently did not take much more time to form. Then, too, the skeleton shows no mineralization nor petrifaction, and is but little discolored to a light brown by the waters of the swamp."

This evidence of recent burial agrees with that concerning two other specimens found in similar condition in the general vicinity, the skeletons of which "look like bones buried but a few hundred years," while between the ribs of one of these (the Warren skeleton of the American Museum of Natural History) "lay from 4 to 6 bushels of vegetable food, largely coniferous and much like spruce or hemlock." Though this is not direct evidence of man's coexistence in America with the mammoth, the recent date of these entombments would make them contemporary with the various relics of man which have been reported in glacial deposits.

This evidence, added to that which has heretofore been adduced[1] would seem to put the coexistence of man and the mammoth in America beyond question, especially as the elephant mounds in Ohio and Wisconsin, and the prehistoric catlinite pipes shaped like the elephant, found in Iowa, give testimony that is unconnected with any theory of geological agencies.

Thus, all over the northern hemisphere evidence points to the recent close of the glacial period, and in connection with it, or following it, a wholesale destruction of many animal species. In North America, the following kinds of great quadrupeds disappeared during that period or shortly afterward: Camels, llamas, horses, tapirs, mastodons, elephants, and three species of giant sloths, of which the *Megalonyx* is most prominent, the latest discovery of which has recently been made by Mr. Gallup, in Norwalk, Ohio. This like the mammoth in Farmington, occurred in a partially filled "kettle hole," left on the withdrawal of the continental ice sheet.

As these remains are found in post-glacial deposits, it is evident that the advance of the continental ice sheet was not the direct cause of the destruction of these species. But in the words of Prof. Osborn, "It is more in accord with the facts to say that the glacial period in North America *originated certain new conditions of life which directly or indirectly resulted in extinction.* These conditions include diminished herds, enforced migrations, the possible overcrowding of certain southerly areas, changed conditions of feeding, disturbances in the period of mating and reproduction, new relations with various enemies, aridity, and deforestation; in short, a host of indirect causes." (*The Age of Mammals*, p. 501.)

* Reprinted from *Records of the Past.*

[1] See *Records of the Past*, vol. ii, pp. 243–253.

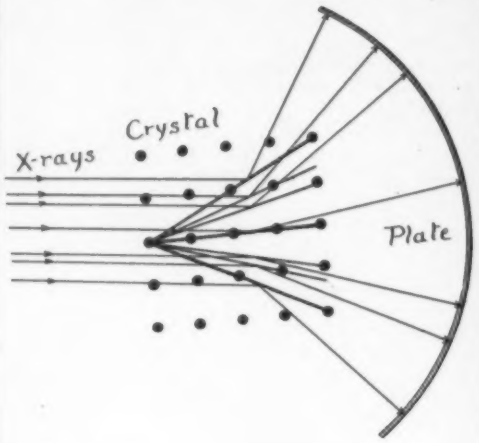


Fig. 1.—Diagram illustrating reflection of X-rays by crystals.

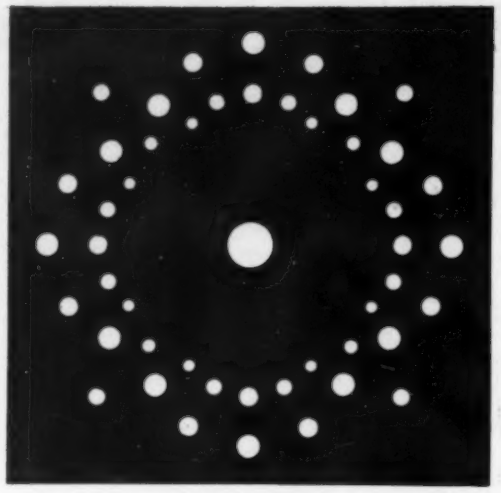


Fig. 2.—X-ray diffraction pattern with potassium chloride.

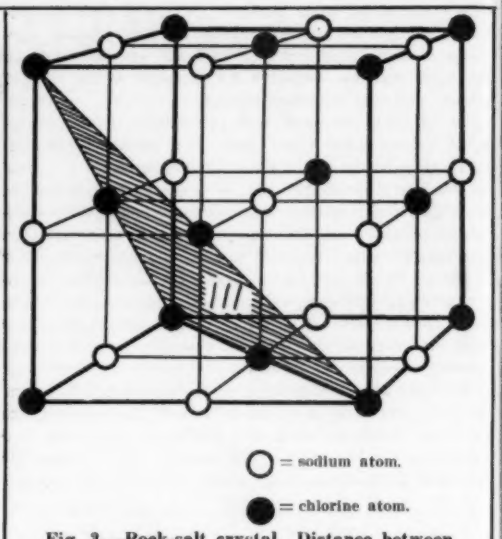


Fig. 3.—Rock-salt crystal. Distance between atoms = 0.0000000101 inch.

New Light on the Structure of Matter

Molecular Architecture Revealed by Roentgen Rays

By Arthur H. Compton, Princeton, N. J.

ONE of the most interesting developments in modern physics is the recent discovery that Roentgen rays can be reflected and diffracted by means of crystals. As an immediate result of this discovery, not only has the true nature of X-rays themselves been learned, but scientists have been able to explore the inner structure of crystals, learning the arrangement of, and measuring the distance between the atoms of which they are built. It even seems as though we may be able to probe still deeper by this means, and find out how the atoms themselves are made.

WHAT ARE X-RAYS?

Though the nature of X-rays has been generally supposed to be similar to that of light, that is, ether vibration of very high frequency, there were those who still defended other hypotheses. There are certain differences which were hard to explain. No one had been able to reflect X-rays regularly, as light is reflected from a mirror; a diffraction grating had never been constructed which would disperse the rays; and the remarkable penetrating power of these rays offered a striking contrast to the action of light waves. These things could all be explained by supposing that the wave-length of Roentgen rays was extremely short, about 1/1,000th that of light, but there were other hypotheses which seemed to give a fuller explanation of some phenomena.[1]

The distance between the molecules in a solid is about a hundred millionth of a centimeter, and supposing the wave-length of X-rays to be a thousandth that of light, these waves would not be very much shorter. So it occurred to Prof. Laue that, if the molecules were arranged regularly, as they are in crystals, they ought to act as a diffraction grating and disperse the rays in much the same way as an ordinary diffraction grating disperses light. Messrs. Friedrich and Knipping tried the experiment by passing a fine beam of X-rays through a crystal of zinc-blende, a short distance behind which was placed a photographic plate. When they developed the negative, they found a remarkable group of spots, arranged symmetrically on four sides of the central image, as in Fig. 2. The true explanation of these spots was given by Mr. W. L. Bragg. He explained each spot on the photographs as being due to the regular reflection of the beam of X-rays from a plane in the crystal, which is especially rich in atoms. For instance, if the atoms are arranged in a simple cubic pattern, as in Fig. 1, the rays would be partially reflected from planes, such as those represented by heavy lines, which contain a relatively large number of atoms, but not from planes taken at random, which do not include many atoms.

The cleavage face of a crystal is very rich in atoms, so to test his explanation Mr. Bragg allowed a beam of X-rays to fall on a cleavage face of a crystal, and found, as he had predicted, that an image was produced on the photographic plate at the angle of reflection. But he noticed that as the angle of incidence was changed, there were certain angles at which the reflection was exceptionally strong. Thus, as in Fig. 5, which represents the intensity of the reflected beam for different angles, at certain very definite positions the reflected beam increased suddenly in intensity. These positions of strong reflection could be explained in only one way, as real spectrum lines in the X-rays—radiation of definite wave-length. This explanation led at once to a definite knowledge of the nature of X-rays.

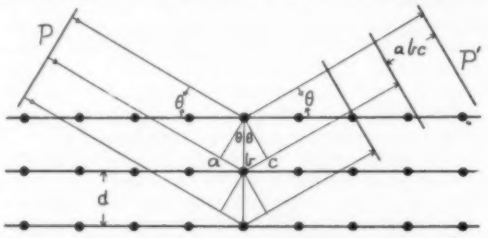


Fig. 4.—Diagram illustrating formation of X-ray spectrum produced by reflection from crystal surface.

In the ordinary X-ray bulb the rays are produced by shooting a stream of electrons from the cathode against a metal plate. When they strike this plate they send out ether vibrations. It is just like shooting at a target with a rapid-fire gun, the bullets replacing the electrons, and the powder the electric field. When each bullet strikes the target, the sudden stopping of its motion sends out a "pulse" of compression through the air which reaches our ears as a thud. If the target is made properly, it will vibrate when struck, and we hear it

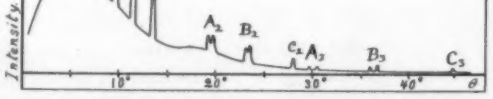


Fig. 5.—Spectrum of X-rays from platinum target reflected by crystal of rock-salt.

ring. In the same way, when an electron strikes an atom in the metal target of the X-ray bulb, it is suddenly stopped, giving out an ether "pulse." At the same time it sets the electrons in the atom itself to vibrating with their natural frequency, which is characteristic of the particular atom. Thus the X-rays are composed of a series of very intense pulses, due to the collisions of the electrons, along with one or more trains of waves of definite wave-length, caused by the resonance of the electrons in the atoms of the target.

When an X-ray pulse strikes the cleavage face of a crystal at a definite angle, as in Fig. 4, a part of it is reflected by each layer of atoms. When its reflection from the first layer of atoms reaches P', the reflection from the second layer is a distance a, b, c or $2d \sin \theta$ behind it, and the reflections from the lower planes are spaced at equal distances behind. Thus the pulse at P is reflected to P' as a series of pulses of definite frequency. It is just the same principle as when a noise in front of a flight of steps or a wicket fence is echoed back as a musical tone. If the pulses are scattered at irregular intervals, each will produce a separate series of vibrations at P', but if they come in a train of waves whose wave-length is $2d \sin \theta$, or some simple harmonic of it, they will reinforce each other at P' and produce an especially strong image. This will occur when

$$n\lambda = 2d \sin \theta; \qquad (1)$$

where n is an integer, and λ is the wave-length of the resonant rays.

Since there are only a very few periods of natural vibration of the atom, there will be only a few definite values of λ, so that this equation will be satisfied for only certain particular values of θ. The reflection of the scattered pulses, however, will be present at all angles. So as θ is increased, there will be a comparatively uniform intensity of reflected rays due to the irregular pulses, and at certain definite angles a sudden increase in intensity due to the resonant rays. This is shown in Fig. 5, which is the spectrum of X-rays from a platinum target as reflected by a crystal of rock-salt. It will be noticed in this diagram that the prominences repeat themselves as θ increases. The different series of lines represent different orders of spectra, n for the first order being 1, for the second 2, and so forth. In this manner our theory of the nature of X-rays accounts perfectly for the form of these spectra.

THE STRUCTURE OF CRYSTALS.

At this time no one knew whether it was the molecules or the individual atoms which did the reflecting. Whatever the reflecting centers were, however, there was now a means of finding out how they were arranged in the crystal. Mr. Bragg imagined a number of different arrangements of these centers, and on the theory that each spot in Friedrich and Knipping's photographs was a partial reflection of the primary beam by some plane rich in atoms, he calculated where the spots should be found for each arrangement. It was found that nothing but a simple cubical design could account satisfactorily for the spots obtained with such crystals as salt, potassium chloride, etc. He was now able to decide whether it was the atoms or the molecules which did the reflecting. By comparing the intensity of the different orders of spectra when the rays were reflected from the (111) plane (Fig. 3), it was shown that the alternate planes of centers differed in reflecting power. On the assumption that it is the individual atoms which act as the reflectors, this was easily accounted for by placing layers of sodium atoms and chlorine atoms alternately parallel to the (111) plane. This gives at once the arrangement shown in Fig. 3, where the open circles represent sodium, and the solid ones chlorine atoms.

It is interesting to notice that there is no evidence in

[1] The theory other than the wave theory which received most support was one put forward by Prof. W. H. Bragg in 1910. According to this theory, X-rays are corpuscles, each composed of an electron and an equal positive charge, which travel with nearly the velocity of light. This theory was made to account for the fact that the "emergent" secondary radiation is stronger than the "incident" radiation, when a beam of X-rays passes through matter. Even this fact, however, was shown by Prof. O. W. Richardson to be consistent with the wave theory of X-rays.

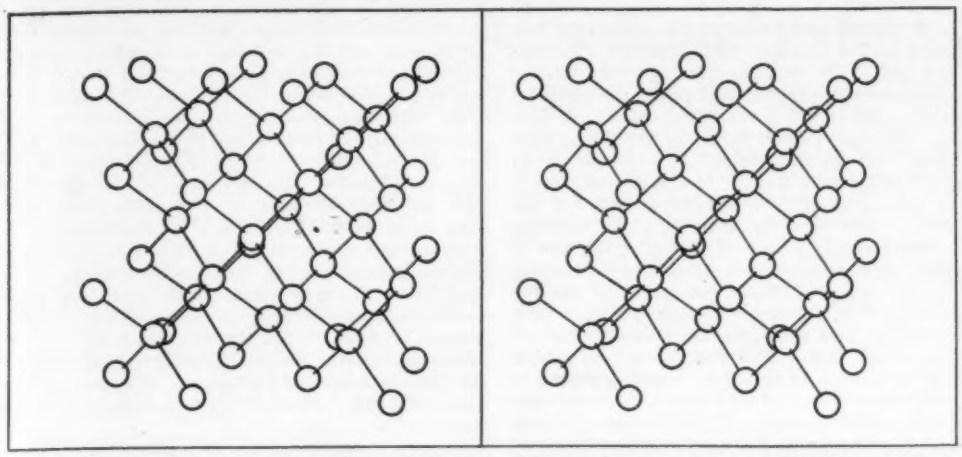


Fig. 6.—Arrangement of atoms in a diamond (Bragg). Distance between atoms = 0.000000015 centimeter. To be looked at in stereoscope.

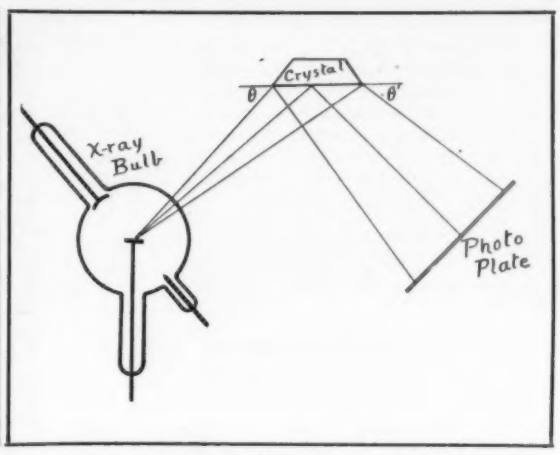


Fig. 7.—Diagram of Moseley's method of photographing X-ray spectra.

this arrangement that the atoms are combined into molecules. A sodium atom is no more closely connected with one particular chlorine atom than with any other. In fact, a crystal, such as the one shown in Fig. 3, may have an unequal number of sodium and chlorine atoms. None of the crystals so far examined have given evidence of any molecular structure. Is it possible that, in the solid state, matter loses its molecular structure, each atom being connected with the whole mass instead of to that particular group of atoms which form its molecule? It would seem to be so, at least for crystals.

Now that the arrangement of the atoms is known, it is easy to calculate their distance apart, and thus to define completely the structure of the crystal. The number of molecules in a gramme of sodium chloride is

$$\frac{6.22 \times 10^{23}}{58.46}$$

where 58.46 is the molecular weight of NaCl; and if its density is 2.167, there are

$$\frac{58.46 \quad 2.167}{6.22 \times 10^{23}} = 2.31 \times 10^{22}$$

molecules, or 4.62×10^{22} atoms, in a cubic centimeter. Since the atoms are arranged cubically, their distance apart is

$$d = \sqrt[3]{\frac{1}{4.62 \times 10^{22}}} = 2.79 \times 10^{-8} \text{ centimeters,}$$

a trifle over one hundred millionth of an inch. Thus, along the edge of a salt crystal an inch long, there are arranged a hundred million atoms.

In much this same way Prof. W. H. Bragg has determined the structure of the diamond. In this case the atoms are all the same kind—carbon. The arrangement he finds for these atoms is shown stereoscopically in Fig. 6. Each atom may be thought of as bound to four other atoms, arranged at the corners of a tetrahedron. This is in accord with the fact that carbon has four chemical bonds, and is in good agreement with the structure of the diamond as determined by the methods of crystallography.

THE STUDY OF X-RAY SPECTRA.

As we now know d, the distance between the atoms in the crystal, we can easily determine the wave-length corresponding to the different lines in the X-ray spectrum. For instance, for the B_1 line of platinum, if it is reflected from rock-salt, when $n = 1$, $\theta = 11$ degrees 28 minutes, so that equation (1) becomes

$$1 \times \lambda_B = 2 \times 2.78 \times 10^{-8} \times \sin \text{ (10 degrees 28 minutes)}$$

$$\lambda_B = 1.100 \times 10^{-8} \text{ centimeters.}$$

Since the wave-length of sodium light is

$$\lambda_D = 5.89 \times 10^{-5} \text{ centimeters,}$$

the wave-length of these X-rays is about one five-thousandth that of light.

One of the finest pieces of work done in the study of X-ray spectra is that of Mr. H. G. J. Moseley,[2] in which he compared the X-ray spectra of a large number of different metals. These metals were used successively as the target of an X-ray bulb, and the rays were reflected from a large crystal of potassium ferrocyanide on to the photographic plate (Fig. 7). Each exposure required about five minutes, and gave the spectrum through a range of wave-lengths of about 30 per cent. Fig. 8 represents the third order spectra which Moseley obtained of all the metals of atomic weight betwen 40 and 65, with the exception of scandium. The remarkable thing about these spectra is their similarity for the different elements. The square root of the frequency which corresponds to the more prominent line of these spectra has been shown to change by a constant difference as we pass from element to element down Mendeljeff's periodic table. This is the only property of matter which has been shown to vary uniformly from element to element.

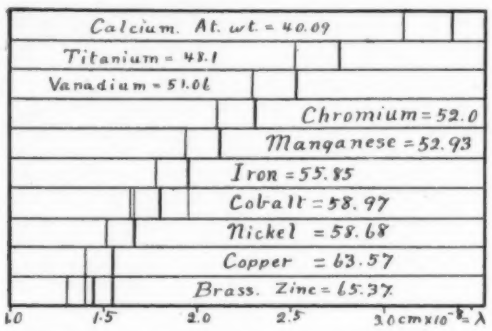


Fig. 8.—X-ray spectra of ten metals, according to Moseley.

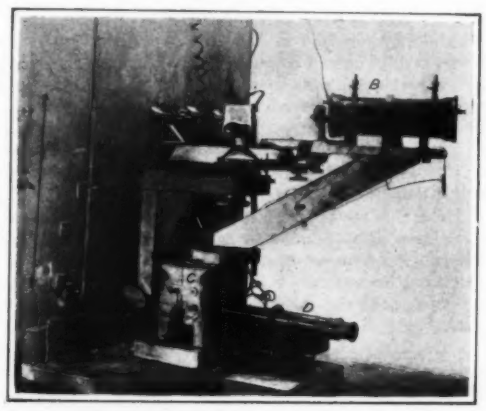


Fig. 9.—Apparatus employed in the study of crystal structure by means of X-rays.

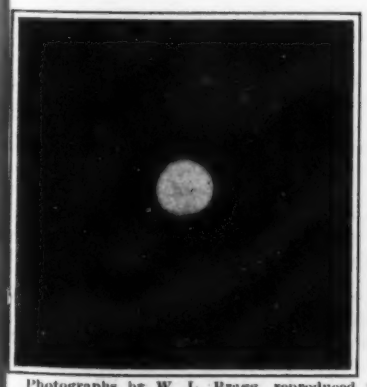
A, crystal; *B*, ionization chamber; *C*, electroscope; *D*, microscope. The X-ray tube is hidden by the partition in the background.

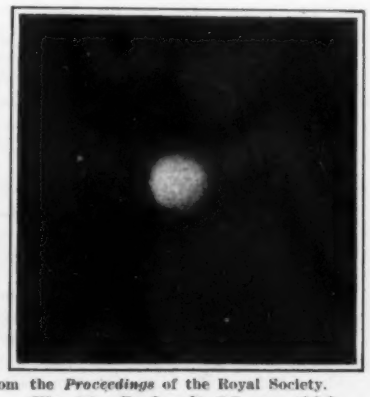
It is evident that this affords a convenient means of finding out where elements are missing. For instance, it is easy to see that an element is missing between calcium and titanium, and even if scandium were not known it would be possible to predict its existence and give approximately its atomic weight and its general characteristics. Moreover, it affords a powerful method of chemical analysis. For instance, the cobalt contained only 0.8 per cent nickel, and the nickel line appears very distinctly in the cobalt spectrum. The ease with which these spectra can be obtained would seem to make the method of considerable value to the qualitative chemist.[3]

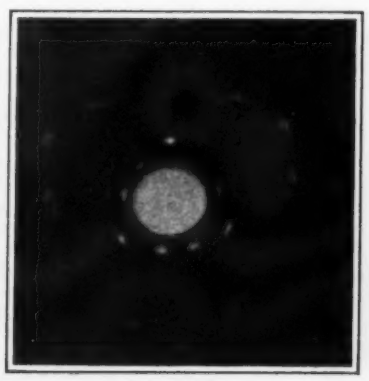
But possibly the most interesting result of this research is the light it throws upon the structure of the atom itself. A number of different theories have been proposed which explain the atom as a nucleus of "positive electricity" about which electrons revolve in orbits, as do the planets around the sun; but none of them have been sufficiently confirmed by experiment to be generally accepted. From the uniformity of the spectra of these elements, Moseley has been able to show pretty definitely that the number of electrons in an atom is equal to the number of the place of the element in Mendeljeff's table. That is, if any element is the *Nth* in the periodic table, counting hydrogen as 1, helium as 2, etc., the total number of electrons in the atom is *N*. Thus each element contains just one more electron per atom than the element next lighter. It seems probable, from his results, that these electrons revolve about the central positive nucleus in concentric rings, much in the same manner as the rings revolve about Saturn. If this is true, there are probably four atoms in the inner

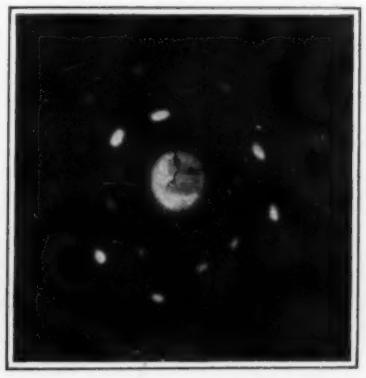
[2] "High-frequency Spectra of the Elements," *Philosophical Magazine*, December, 1913.

[3] In the last number of the *Philosophical Magazine* (April, 1914), Mr. Moseley has given the X-ray spectra of thirty-nine different elements, showing that this constant change in the character of the spectra holds for all the elements, from aluminium to gold. He shows that gold is the seventy-ninth element in the order of atomic weights, and has predicted the position of three new elements. The position of these elements is (1) between molybdenum and ruthenium, (2) between neodymium and samarium, and (3) between tungsten and osmium. Chemists are now at work hunting for these elements.









Photographs by W. L. Bragg, reproduced from the *Proceedings* of the Royal Society.

Fig. 10.—Potassium chloride. Fig. 11.—Rock-salt, 2.5 mm. thick. Fig. 12.—Fluorspar. Fig. 13.—Rock-salt.

ring for the elements whose spectra are shown; but this has not yet been established definitely.*

It is hard to tell to what these researches may lead in the near future. Already the structure of a dozen different crystals has been determined, the nature of X-rays has been found out, and light has been thrown upon the manner in which the atom itself is built. It may be, as Sir Oliver Lodge suggests, that the study of reflection of X-rays by crystals will form by itself an important branch of modern physics.

* This theory of the structure of the atom was proposed by Dr. N. Bohr (*Philosophical Magazine*, July, August, September, 1913). Moseley showed that his photographs confirmed this theory in a very striking manner.

The Metric System*

By Alexander Siemens

SINCE its introduction into the United Kingdom, the metric system or question has had its ups and downs. Surely it is very curious that, although in 1862 a Parliamentary Commission recommended its introduction—a recommendation since repeated two or three times—and though a bill was actually passed by the House of Lords, the metric system has not been adopted in this country. Why do people go on agitating? Well, the reason is the necessity for such a system. The facilities for intercommunication between various countries have a great deal to do with the continual agitation to introduce an international system of weights and measures. You may say the first person who put this down in black and white was James Watt. Writing to a friend in 1783 he said it was very awkward that the scientific results of workers in various countries could not be compared readily because of the measurements and weights being so different, and he proposed that they should agitate for the adoption of an international unit of weights and measures for scientific purposes. He wrote to French savants on the subject, and the result of the agitation was that in 1790 Prince Talleyrand brought in a bill before the Legislative Assembly of France proposing that a Commission should be nominated to deliberate on this subject. It was a provision of that measure that the Royal Society of London and the French Academy should nominate the members of the Commission because it was agreed that the Commission ought to be an international affair and not merely a nati nal one. The Royal Society would not agree to it because, as you know, England and France were at war at that time. Eventually, however, some other countries joined and constituted a Commission.

Another feature of the metric system was also suggested by Watt. He suggested that the unit of length should be cubed, a vessel constructed, filled with water at its greatest density, and that that should be the unit of weight. This cube should be the unit of capacity. In carrying out this idea insuperable difficulties have arisen of an absolutely mechanical nature, and so a kilogramme is not any more a decimeter cubed and filled with water, but it is a piece of platinum kept in Paris at a certain temperature and at a certain barometric pressure. But the difference is very slight and does not affect the value of this co-relation between length, capacity and weight. That is just the same as the standard of British measure—in fact, the real standards of English weights and measures were burned in 1835 in the Houses of Parliament and had to be reproduced afterward as best they could. Secondary standards have now been made and have been distributed over the country, so that there is no danger of the standards being lost again.

After giving you this short history of the beginning of the metric system, I wish to direct your attention to the greatly different circumstances of communication between the various countries from what formerly existed. The interchange of products between the various countries has increased very much, and it is to the interests of everybody that this interchange should be facilitated as much as possible. One of the greatest facilities is that the same weights and measures should be used everywhere. Now the real requirements of such an international system are two in number. One is that the measures and weights should have the same base ratio throughout; that means to say one pound in the English system should be 16 ounces; one ounce should be 16 drams; one foot 16 inches; one yard 16 feet, and so on. That would be a system with the same base ratio throughout. Only 16 is not a good one. I am, of course, aware that people say 12 is a good ratio because there are so many aliquot factors in 12—three times four, twice six—and that consequently 12 is handy. We are, however, faced by the fact that all people on earth who count, count by tens, and that has fixed the base ratio for any international system. If you attempt to put in any other ratio it would lead to confusion, and would not be so convenient. Therefore the base ratio of 10 is essential.

Now as regard a little more of the history of the metric system. In 1861, the old Federation of German States instructed a Commission to propose a national system of weights and measures, and after they had deliberated a short time they came back to the Federation and said, "We must say that the only sensible thing"—the only thing that would justify the upsetting of the old measures which were very confusing in Germany at the time—"the only reason for disturbing people and introducing new weights and measures can be to have an international system." At that time the metric system was not as widely introduced as now, and the Commission very carefully went into the question whether they should adopt the English or the French system of weights and measures. It must be remembered that the superiority of England at that time was still very overpowering. It was a little less so than in 1850, but still it was preponderant. The United States and Colonies of England all had the English system of weights and measures, so this Commission, consisting of sensible men, might have thought: "We will go with the majority of the manufacturing people and adopt their weights and measures." But when they saw the English weights and measures and went into them, they unanimously decided that the metric system was the only possible international system In the metric system there is the same base ratio and divisions everywhere, so you have to learn nothing. It is the same base ratio as you use in calculation. I remember in 1895 I had to give evidence before the Parliamentary Committee on Weights and Measures, and I handed in a German school-book on arithmetic. The Committee said: "How many pages are devoted to the metric system?" I showed them that on the back cover there was a note: "Remember a hectoliter is 100 liters; a kilogramme is 1,000 grammes." The other things were so self-evident that it was considered unnecessary to say anything about them.

The Commission instituted by the old Federation of German States submitted their proposals to the Reichstag in due course; then came the year 1866, which delayed the introduction somewhat, but in 1868 the Act was passed that the metric system should be permissible from January 1st, 1870, and compulsory from January 1st, 1872. This disposes of the idea that the metric system can only be introduced in times of great commotion and so on. The date of the introduction of the metric system was decided upon long before anybody knew anything about the Franco-Prussian War, and was, therefore, introduced rather in spite of it than as a consequence of it. About the same time a Committee was appointed by the English Parliament to report on the introduction of the metric system, and after hearing all sorts of witnesses, they reported in 1862 that "in their opinion it would involve almost as much difficulty to create a special decimal system of our own as simply to adopt the decimal metric system in common with other nations. Furthermore, if we did so create a national system we would in all likelihood have to change it again in a few years into an international system owing to the increase of commerce and intercourse between nations."

More than fifty years ago the upshot was that the Committee said it would be a waste of energy to introduce a special English system because, owing to the ever-increasing intercourse between nations, the nations would be forced into the adoption of an international system whether they liked it or not. That is the real reason why the Decimal Association believes that the metric system is coming. It may be coming slowly, especially here in England—we cannot help that—but if you consider this point of view, that the international intercommunication is every increasing, that the nations are becoming more and more dependent upon the produce of other nations, you will see—you must come to the conclusion that an international system of weights and measures is desirable, and that the refusal of such a system will impede progress.

What are the objections? The first that is made is to the decimal point. Owing to the base ratio being 10, and 10 throughout, there is no necessity to use a decimal point. For instance, anybody making drawings puts all the dimensions on the drawings in millimeters. That has two advantages. You need not put millimeters every time as you put feet and inches (′, ″), and it avoids a lot of misunderstanding if the drawing has not been very carefully figured. 1′ 1″ is often taken for 11 inches, 2′ 4″ for 24 inches, and all that sort of thing, but if you use millimeters you have not that difficulty.

The decimal point objection is really non-existent because you always take the next lower unit if you find that what you want to express is less than the higher unit, and that is generally quite sufficient. The second objection taken is the size of the unit. That really is an argument that shows into what desperate straits the opponents of the system have reached to find an objection, because I cannot for the life of me see that the meter and the yard are so very much different. Nor are a half-kilogramme and a pound so very unlike each other.

The next thing is that the opponents of the compulsory introduction of the metric system say: "Well, you have got all you want, you have permission to use the metric weights, the Board of Trade will verify them for you; they have the standards—so what more do you want?" That is just it. Do not these people see that in compelling manufacturers and traders to have two standards, one for home consumption, and one for dealing with metric countries, they handicap the manufacturers and traders here? And there is another point of view. There was a discussion before the Institute of Inspectors of Weights and Measures on the metric system; they are the people who go about among all the tradespeople and have to verify weights and measures, and they ought to know their business. One inspector said that "from the inspector's point of view there is one point which advocates should not favor, and that is the argument that the proposed general Act should be permissive. To have two sets of weights on the shop counter at the same time is not wise. We know what it would be to have a 14-pound set and a kilogramme set alongside the scale; the changes would be rung. The kilogramme is very near the size of a 2-pound weight; the meter near the length of the yard, and the liter near the size of a quart. With these facts before us, the Act should, in our opinion, be compulsory."

These are the two arguments: So long as it is permissive, people who deal with metric countries have to have two standards, and they are handicapped in that way, and poor people are exposed to the danger of being defrauded.

The last objection is on the ground of cost. In order to have a fair idea of what the cost would be, it is preferable to examine in detail how various interests would be affected if the metric system were made compulsory after a transition period of, say, two years. Taking first the case of the retail trader with whom the general public have most of their dealings. I think it fair to quote an inspector of weights and measures who spoke in the discussion just now alluded to. He said: "The change to the metric weights and measures would really be very little cost to the shopkeeper, but he does not realize that this is the case. The shopkeeper imagines that the whole of the weighing machines and weights have to be changed, and it is the weighing instruments that are the greatest factor with him. The effect so far as weights and measures are concerned is very small indeed. It does not cost much to change either his weights or his measures, and I refer to measures of length as well as to those of capacity. With regard to the changing of lever machines, we know as inspectors that it is a very common thing for a weighing-machine maker to have to change the whole of his steel-yard markings and to have to rub out the old markings and to mark it anew. In this case it would be a very easy thing to change the markings, which would also apply to platform machines and counter-poise weights. The cost would be very small indeed." We may take it on the authority of the persons whose business it is to know everything about the weights and measures of the retail trade that the cost of the change would not be an insuperable obstacle.

The next interest to consider is the textile trade. Here, the opponents of the system contend, the cost of the change would be appalling, because all present looms would become obsolete and would have to be replaced by new ones adapted to produce metric widths of fabrics. I had better take that with the engineering trade, because about that the same is said. I say in reply to all these arguments, "What are you doing now? Are you not exporting to metric countries, are not engineers exporting to metric countries? Have not we in our works plenty of metric dimensions to manufacture to; have we ever found any difficulty in doing it? Have we ever had to introduce new machinery specially to make a metric thing? Never!" Even leading screws of English pitch can be used to produce screws of French pitch and *vice versa*. You must put in one wheel with 127 teeth which makes the changes right. You will find you are absolutely correct. When before a Parliamentary Committee I was asked: "Seeing that in the cotton trade the standard make is what is called 79 inches, 37½ yards, 8¼ pound shirting—which is known all the world over—would it not in some way damage the reputation of the shirting if the figures had to be recalculated in all the markets of the world?" Well, at the time I had not sufficient time in which to make the calculation. What do you get when you recalculate? Seventy-nine inches are 2 meters within one third of 1 per cent; 37.5 yards are equal to 34 meters to within one third of 1 per cent; and 8¼ pounds are 3¾ kilogrammes. So you see you have been entertaining angels unawares. You have been manufacturing to metric measure. So why say it is difficult? The general experience is that wherever the metric system has been introduced it has at once been accepted as by far the simplest and easiest to comprehend, while it has the great advantage of being international, which is more and more necessary nowadays where the intercourse between countries is increasing.

* From a report published by the Decimal Association of an address to the members of the Bradford Textile Society and of other Trade Organizations at Bradford, and reported in *Nature*.

In the Open Yellow Pine Forests of Washington and Oregon a collapsible plow is being used in digging fire lines to stop surface fires. The plow can be dismantled and folded into a compact form, so that it can be packed on horseback, and weighs only 40 pounds. When in use, one man with a horse can do the work of twenty or more men working with shovels.

A Built-up Model Yacht

Directions for Its Construction

By F. D. Banham

A METHOD of building a boat is here described which is far less laborious than boring and chiseling out a solid block; the hull, in the particular model described, being made by taking three pieces of board, cut to the dimensions given later, and screwing the pieces temporarily together, one above the other (Fig. 1), and shaping the outside of the hull to the correct shape; afterward taking apart the three pieces and cutting out the center of each separate board with a pad-saw. The three pieces are then reassembled permanently to form the finished hull. The plans are for a 2-foot overall yacht. If another size is desired, proportional dimensions can be taken.

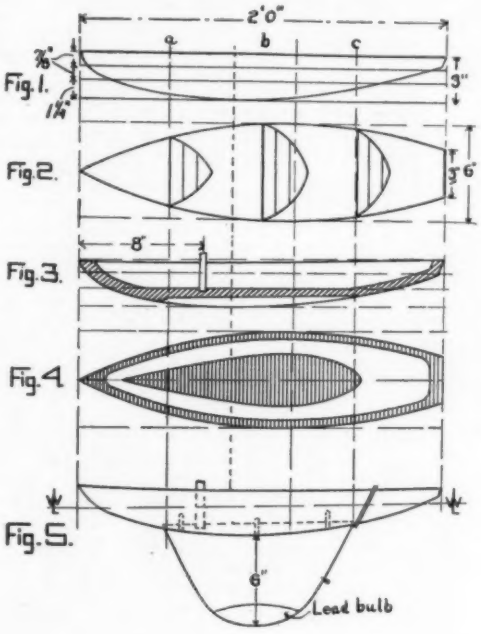
For the amateur, straight grained sugar or yellow pine, or redwood, are the easiest to work. Three pieces finished smooth on each side are required. One piece, 25 by 6½ by ⅞ inch; one 24 by 6 by ⅞ inch; one 20 by 5 by 1¼ inch. Lay out the design in full size on a sheet of paper; follow out the sketch as closely as possible, being careful to get good easy curves. From the sectional curves taken at points *a b c* (Fig. 2) the width at these points on each layer, or board, can be obtained. Make a plan of the top surface of each layer on the board from which it is to be cut, and saw just outside of the line, say ⅛ inch. At the point *b* on each layer draw a line at right angles to the lengthwise line, as a guide when assembling the pieces together before shaping the hull. When each piece is cut roughly to shape they can be screwed together with say 2 screws each. To aid in getting the correct shape, 3 molds should be made from thick cardboard or thin wood. Three rectangular pieces about 5 by 8 inches should be made, and the outline of the sections at *a b c*, as shown in Figs. 1 and 2, should be drawn on the wood or card, and a piece cut out carefully to the line.

After shaping the hull on the outside till it fits the molds at their respective places, it can be taken apart again; care should be used not to break the edges. With a key-hole saw, or pad-saw, cut out the center of all but the bottom layer (Fig. 4), cut on the slant where needed to follow the outline of the outside; ⅝ inch along the center of the boat will be thick enough, and at the bow and stern where the slant is greater from ¾ to 1 inch should be left for strength and to leave enough in which to drive the fastening nails. After cutting out the center of the layers they are ready for gluing and nailing together. Nail every two inches along the edge with about No. 18 gage by 1½-inch wire brads.

The hull being assembled, it can be laid upside down and a groove cut down the center of the bottom layer about ½ inch deep for the keel plate to fit in. The plate should be a fairly tight fit in the groove. The keel can be cut from a sheet of iron or brass 3/64 or 1/16 inch thick. The forward and after edges should be filed to a thin edge.

The lead bulb is made in two pieces, one on each side of the keel plate, and the total weight will be about five or six pounds for bulb and keel. If shaped as shown, one wood pattern will do for both sides. A wood pattern is made the shape of the lead bulb. Each half of the bulb will be about one half inch thick, 6 inches long, and 1¾ inches deep. A mold is then made with the wood pattern in sand, or plaster of Paris, which should be carefully dried before using, and the molten lead can then be poured in the mold. When cool two ⅛ or ¼-inch holes should be drilled through bulb and pin, and two soft brass rivets used to hold the bulb to the keel-pin. If no facilities for drilling are available the bulbs can be soft-soldered to the keel. Three pins of ¼-inch diameter rod are fitted to the top edge of the keel plate, and are held in place by sawing or filing a slot, down one end of the pin, for about ½ inch, to fit over the edge of the keel, and the other end is threaded to take a ¼-inch nut. The slotted end is slipped over the edge of the keel and a cross-hole is drilled through pin and plate and a wire rivet is driven in the hole. Three ¼-inch holes are drilled up through the bottom layer of the hull for the pins to pass through, and a nut and washer holds the keel firmly in place. Put some thick paint or putty in the groove before finally screwing keel in position.

Before putting on the deck, curve or camber the top edge of the hull; in the center of the boat the curve will be about ⅛ or 3/16 inch below the straight edge (Figs. 3 and 5). The mast steps in at the distance shown (Fig. 3). The best way is to set in a brass tube



of about ½ inch inside bore so that the mast can be taken out when desired. An old fishing rod joint makes a good fitting for the bottom end of the mast. The bottom end of the brass tube should be tightly plugged with a wood or metal plug so that no water can enter the hull from this point. The deck should be of ¼-inch wood, and can be cut slightly large, and finished flush with the hull when screwed in place.

If a rudder is to be used, another hole will be needed through the deck to the underside of the hull, just behind and parallel with the after edge of the keel. This is to allow a small brass tube of about 3/16-inch bore to pass through. The rudder post then passes up through the tube. The tiller is bent aft, parallel with the deck and about ¾-inch above it, and is about 3 inches long. Small lead weights are made to clamp or screw along the tiller, and so, by operating the rudder, as the boat heels over when sailing, keeps it on a straight course. Putty or thick shellac should be placed around where the tube passes through the hull and deck, to prevent water entering the hull. The rudder post is a brass wire passing freely through the tube and the rudder can be made of sheet brass about 1/16-inch thick and soldered to the wire post; a small brass eye is soldered to the edge of the keel to take the bottom end of the rudder post. The mast tube should allow the mast to rake, or lean, slightly to the after end of the boat.

The deck, after placing some putty along the top edge of the hull, can then be screwed in place with small wood screws placed about three inches apart. The hull is then ready for sand-papering and varnishing and painting. The deck should be varnished and the hull can be painted white above water-line and dark green or black below water. Two or three coats of varnish or paint should be given.

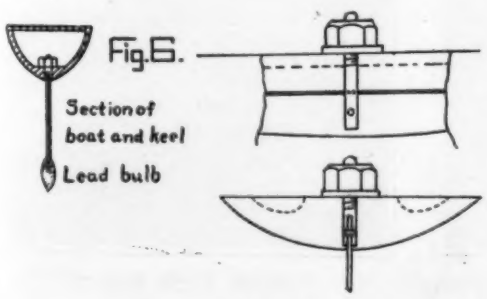
For the sails and rigging as few parts as possible should go to the make-up. The mast should stand 1 feet 9 inches above the deck, and should be ½ inch diameter at the deck to fit in the brass socket, and taper very slightly up to a point a little above the point where the gaff meets the mast, and from there up to the top tapering to ¼ inch. The boom is ⅝ inch diameter at ⅔ its length from the mast and tapers to ¼ inch at the ends. The gaff is 14 inches long and ¼ to 3/16 in the middle and tapers slightly to the ends.

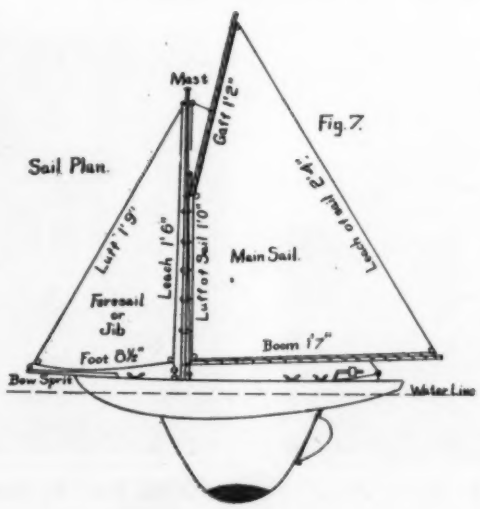
The bowsprit is 7 inches long and projects 3½ inches beyond the bow of the boat; it is ¾ inch wide along the deck and ¼ inch thick, and the out-board end tapers to ¼ inch in width. A supply of small brass screw-eyes such as are used for hanging small pictures will be found useful for rigging the boat. At the in-board end of the boom, where it joins the mast, two screw-eyes are used; one is screwed into the end of the boom, and the other with the eye opened slightly so as to allow the other eye to be hooked under it, completes this fitting.

The yoke for the gaff can be made of brass wire or filed up from sheet brass 1/16 inch thick, and the spiked end driven in the end of the gaff. A little shellac on the spike will help to hold it securely.

Travelers for the mainsail and jibsail can be made of brass wire bent to shape and with the ends flattened out and drilled for small screws and screwed to the deck, or two screw-eyes with a cord traveler and a ring for the sheet to pass through may be used. Cleats are made from strips of brass and drilled for small wood screws to screw onto the deck. Cleats are shown on the rigging plan (Fig. 8) at *C*, and screw-eyes at *E*.

For the sails cambric or the lightest cotton cloth should be used. Sewn or brass shoe eyelets can be used at the corners, and the mainsail laced to the boom and gaff with heavy thread and needle. Fitting loosely around the mast, and spaced equally along the luff of the mainsail and fastened to it, are 5 or 6 rings of brass wire, to keep the sail to the mast. Wire hooks are passed and bent through holes in masthead and end of bowsprit for the hoists, etc.

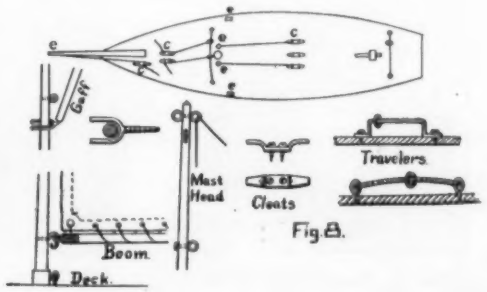




Observations of the Afterglow

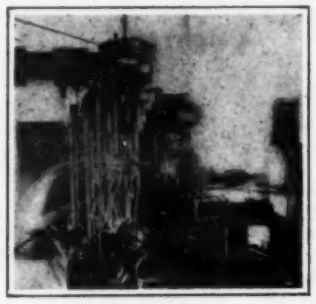
By B. Thieme

A PRELIMINARY communication describes briefly several new observations on the afterglow produced in the gas of a low-voltage carbon-filament lamp after a discharge has been passed, by placing it in an alternating field of high frequency (a Tesla field). The conclusion is that the afterglow is a periodic discharge occurring about 30 or 40 times per second, the period becoming smaller the longer the duration of the effect. Experiments on the discharge which occurs when the bulb of the lamp is electrified by friction are also described, with the conclusion again that the discharge is periodic. Further experiments are being made, on which the authors expect to report later.—*Verhandlungen der deutschen physikalischen Gesellschaft.*



Discharge, Prickwillow.

Suction, Prickwillow.



Engine, Wisbech.

Suction at Wisbech.

Modern Pumping Machinery*

As Employed for Drainage of the Fens, England

By Richard W. Allen

THE drainage of that large tract of low lands known as the Fenland (Lincolnshire, England), comprising over 450,000 acres, is generally but little understood. That the subject is full of interest, and the mechanical devices so varied, will be acknowledged, when it is mentioned that to-day the following methods are employed for carrying out this great work, without which the land would be entirely unproductive:

(*a*) Windmills driving scoop-wheels.

(*b*) Beam-engines (single and compound cylinder) driving scoop-wheels.

(*c*) Beam-engines and horizontal engines driving vertical-spindle pumps through gearing.

(*d*) Vertical steam-engines driving horizontal-spindle centrifugal pumps.

(*e*) Horizontal oil-engines driving horizontal-spindle centrifugal pumps.

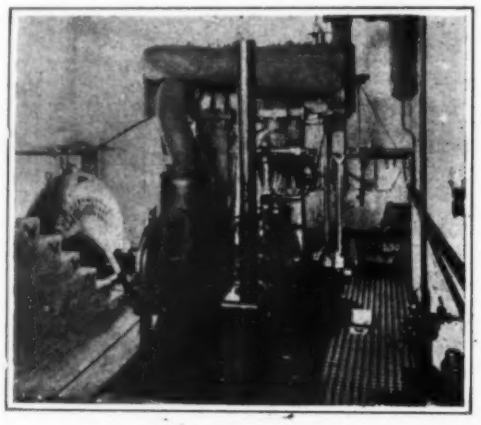
To describe in detail the mechanism under each of these headings would be quite beyond the scope of this paper, and the author therefore proposes to deal chiefly with those which are included under headings (*d*) and (*e*).

(*a*) *Windmills driving Scoop-wheels.*—This type of machinery is rapidly disappearing; the largest example now working is situated on the banks of the River Ouse at Harriermere, Middle Fen District, near Ely, the scoop-wheel being 30 feet in diameter with 5 feet by 14 inches ladles, Fig. 1. The dip of water on the ladle is 1 foot 9 inches and the maximum lift to which the wheel is capable of working is 10 feet. This mill has four sails, 40 feet long by 7 feet wide, and the ratio of gearing gives four revolutions of the sails to one of the scoop-wheel.

(*b*) *Beam-engines driving Scoop-wheels.*—This class of machinery is gradually being replaced by more modern pumping engines, due in many cases to the fact that the subsidence of the land has been so great, varying from ¼ inch to 1 inch each year, that the present level of the various main drains is too low to allow sufficient dip on the ladles of the scoop-wheels.

(*c*) *Beam and horizontal Engines driving geared vertical-spindle Pumps.*—A difficulty now being experienced with many of the existing vertical-spindle pumps, is that, in order to charge the pumps, the water in the drains has to be raised to such a level that there is grave danger of some of the lowest lying land being flooded before the machinery can be set in operation. The cost of lowering the scoop-wheel or the pump, as the case may be, is such an expensive matter and the efficiency under the most favorable conditions so low, that it is more economical to remove the old plant and replace by more modern machinery.

(*d*) *Vertical Steam-engines driving horizontal-spindle centrifugal Pumps.*—During the past fifteen years a number of pumping plants have been installed, in the majority of cases new machinery included under clause (*d*) replacing existing appliances for raising water.



Engine House, Prickwillow.

Discharge, Soham Mere.

For purposes of illustration, the author has chosen some of the following stations in which he has been interested, representing some of the most recent work in the district; but, at the same time, he wishes it to be understood that there are many other stations, such as those erected at Laneham, Puddock Bridge, and in the North Level, which are doing excellent work:

I. Prickwillow, Middle Fen Commissioners.
II. Wisbech, Waldersea District Commissioners.
III. Soham Mere, Dunn Gardner Estate.
IV. Mr. Martin's Farm, Hilgay.
V. Ten-Mile River Bank, Littleport and Downham District.

Before describing the pumping stations in detail, it may be interesting to give in condensed form the main points to be considered in the design and construction of drainage machinery suitable to the conditions obtaining in this area:

(1) In the wettest season the machinery only works five to six months during the year, and in a dry season only three to four months, and sometimes less.

(2) Initial cost has to be kept as low as possible, as the Fen Commissioners have seriously to consider their drainage tax.

(3) Plant to be so designed as to run continuously for at least a month.

(4) The machinery will generally be run by a skilled laborer, not a mechanic. Simplicity is therefore essential.

(5) Water for boilers and for condensing purposes always contains a large percentage of mud in suspension, and this particularly so during the wettest time of the wet season.

(6) Efficiency to some extent must be sacrificed to initial cost and simplicity of design.

(7) Cost of maintenance and renewals must be reduced to a minimum.

(8) All calculations must be based upon amount of coal consumed to the water horse-power discharged.

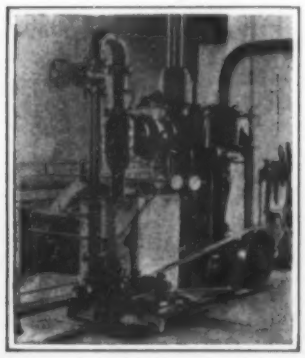
(9) When new plant is installed, the old foundation must be utilized as far as possible.

(10) All new foundation work, unless well stepped into existing foundations, must be placed upon piled ground, or reinforced concrete employed.

(11) The maximum quantity of water has to be always discharged upon the highest lift.

These considerations have been met to a very large extent by the machinery installed at the stations already referred to, due especially to the fact that the centrifugal pump applies itself so well to differences in level of the water in the drain and river. The suction and discharge pipes of the centrifugal pump with a horizontal spindle are laid in the old race of the scoop-wheel with very little cutting away or filling in, and, by extending these pipes outside the building, little or no alteration is required to be made to the main walls of the engine-house. The foundations necessary for the engines are small and easily made in the original engine-house, and further, the

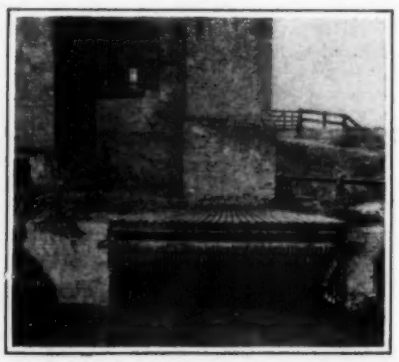
* Paper read at the Cambridge meeting of the Institution of Mechanical Engineers (England).



Engine room, Soham Mere.

Main drain, St. Martin's Farm.

Engine and pump, St. Martin's Farm.

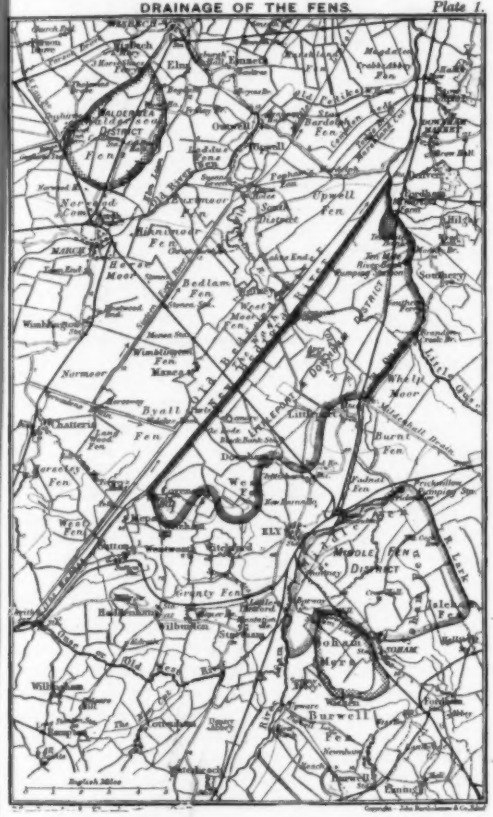


Suction, Soham Mere.

xtra length of suction pipe can be readily added when equired to meet any lowering of the main drain, due to ubsidence of the land.

From experience gained, the machinery most suitable is that consisting of Lancashire boilers, vertical double-acting enclosed forced-lubrication engines running at a moderate speed driving direct centrifugal pumps with horizontal spindles, the condensing plant of the jet type having the injection water well strained before reaching the condenser, and the air-pumps driven either direct from engines or by gearing running in an oil-bath. It is upon these lines that these pumping stations have been designed, with the exception that engines of the open type have been supplied in place of those of the enclosed. This has been brought about by hesitation of the Fen Authorities to depart from the exceptionally low revolution engine, although in many cases the piston-speed of the enclosed engine proposed has been less than that of the open-type engine, yet permission to install the former has not so far been granted.

Water-tube boilers, steam-turbines and surface condensing plants have on occasions been suggested as an alternative, but the author ventures to think that their

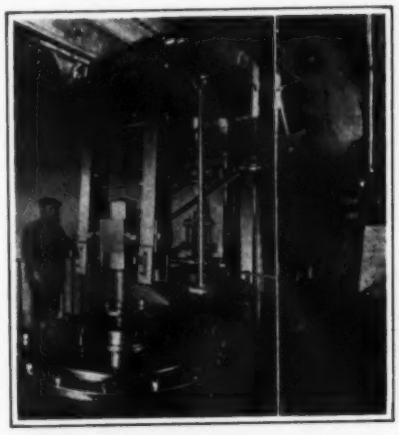


Map of the Fen District, Lincolnshire, England.

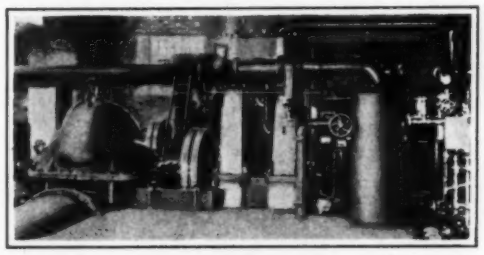
claim does not show sufficient merit to warrant their acceptance, as the slight gain, if any, in efficiency would not show sufficient return to cover the interest upon the increased initial capital expenditure; further, it might be necessary to duplicate the machinery to enable the cleaning of the boilers and condensers to be carried out efficiently; and, lastly, the unsuitability of the feed and cooling water for this class of machinery.

I. Prickwillow, Middle Fen District.—This pumping engine was installed in 1897 replacing a side-lever condensing engine of 60 nominal horse-power, erected in 1833, using steam at 6 pounds per square inch, and driving a scoop-wheel 33 feet 6 inches in diameter.

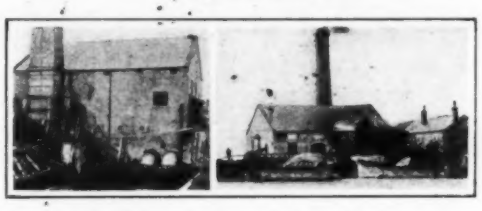
The machinery, Fig. 2, consists of a vertical compound double-acting condensing open engine, driving direct a horizontal centrifugal pump. The steam-cylinders are 21 inches and 35 inches diameter, each having a stroke of 1 foot 8 inches. The engine is capable of developing 300 indicated horse-power with steam-pressure at 75 pounds per square inch. The diameter of the suction and delivery pipes is 43 inches, and the pump is capable of delivering 150 tons of water per minute upon a 16-foot lift at 130 revolutions. The revolving disk is 5 feet 6 inches diameter, and is made of cast-iron and keyed to a steel shaft, running in white-metal bearings. The



Old beam engine, Ten Mile River Bank, Littleport.



Compound condensing engine and centrifugal pump installed in 1912.



Suction Discharge.

pump is provided with steam-ejector, for the purpose of charging. The engine has fixed on the high-pressure crosshead a connecting-rod with reciprocating beam, the levers of which are connected to a single-acting air-pump, 20 inches diameter by 10 inches stroke. Attached to the air-pump is a jet-condenser, giving a constant vacuum of 26–27 inches, steam being supplied by two Lancashire boilers, 23 feet 6 inches by 8 feet diameter, with Galloway cross-tubes.

From March, 1912, to March, 1913, this engine ran on 209 days (of 12 hours duration), the maximum non-stop run being 372 hours during the latter part of August. The average coal consumption was 3½ tons for the 12 hours, including the raising of steam in boilers.

This district has a taxable area of 11,000 acres and about 25,000 acres to be drained, and to-day the drainage is mainly carried out by this pump, assisted by a 60 horse-power compound condensing beam-engine driving a vertical spindle pump, the engine being supplied with steam at 65 pounds pressure. The main drain is 30 feet wide and 7 feet deep at starting level, and there are about 30 miles of drains connected thereto.

The capacities of the old and new machinery may be of interest, and are tabulated below. It will be noted

Type of plant.	Date of erection.	Steam pressure.	Revolutions of engine.	Lift in feet.	Water lifted.
		lb. per sq. in.	per minute.	ft. in.	tons per minute.
Side-lever condensing engine driving scoop-wheel.....	1833	6	25.5	9 10¾	68.9
Vertical compound condensing marine engine direct-driving horizontal centrifugal case-pump.....	1897	76	132	13 4	153.2
	1913	—	——	15 4	——

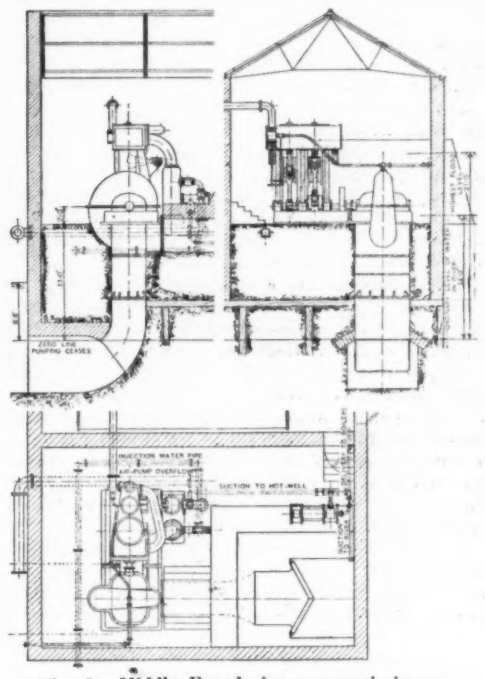


Fig. 2.—Middle Fen drainage commissioners Prickwillow pumping station.

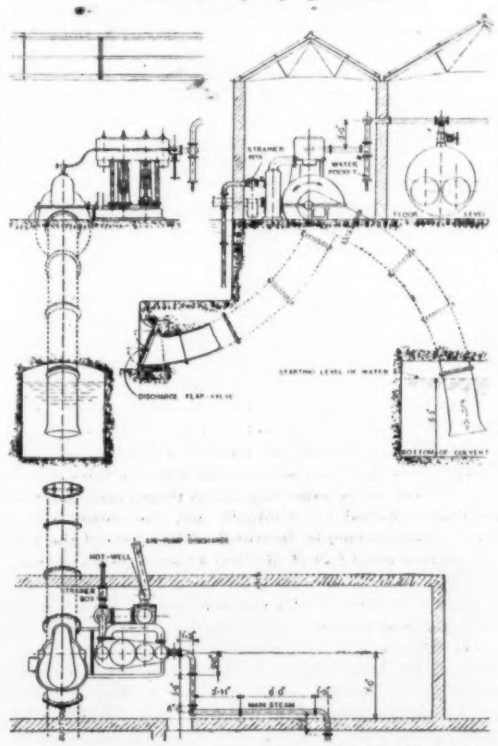


Fig. 3.—Waldersea drainage district Wisbech pumping station.

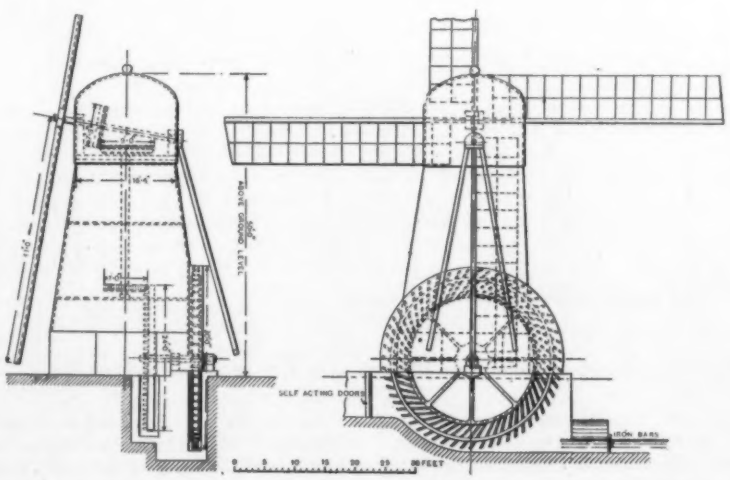


Fig. 1.—Windmill at Harrier Mere driving 30 feet diameter scoop-wheel. Middle Fen District.

that, owing to the subsidence of the land, the lift of the pump has increased in 16 years from 13 feet 4 inches to 15 feet, and in 80 years it has increased practically 6 feet.

II. Wisbech, Waldersea District Commissioners.—This machinery, Fig. 3, was erected in 1900. It consists of a vertical compound double-acting open engine driving

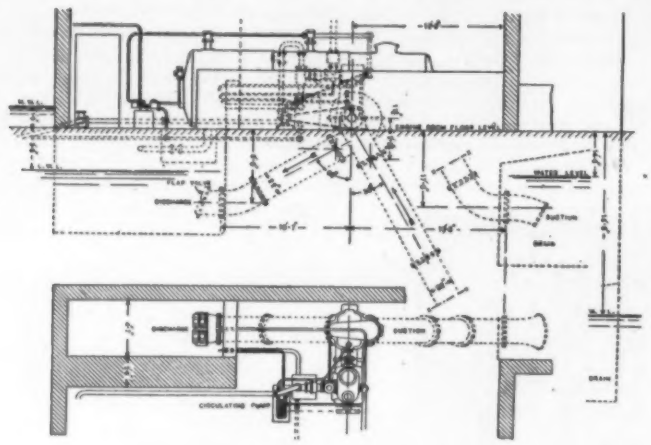


Fig. 4.—Soham Mere pumping station.

direct a horizontal-spindle centrifugal pump. The engine has cylinders 18 and 29 inches diameter by 16 inches stroke, and is capable of developing 200 horse-power, when running at 130 revolutions per minute. It is supplied with steam at 90 pounds per square inch from two Lancashire boilers, 29 feet by 7 feet 6 inches diameter. The diameter of the suction and discharge pipes is 36 inches, and the pump is capable of discharging 100 tons of water per minute against a total lift of 15 feet, the diameter of the disk being 4 feet 6 inches. A jet-condenser is provided giving a constant vacuum of 26 to 27 inches. The air-pump, 16 inches diameter by 9 inches stroke, is worked from the high-pressure crosshead.

This district consists of 5,000 acres and its waters are discharged into the River Nene about 5 miles above Wisbech. It was originally drained by two engines, one erected in 1832, a Cornish beam-engine of 70 nominal horse-power working a bucket-pump 62 inches diameter with 7 feet 6 inches stroke, and the other erected in 1883, a single cylinder condensing engine driving a vertical-spindle centrifugal pump. The former plant was removed in 1900 and replaced by the machinery described above, the old well being used for the suction pipes of the pump. Practically no alteration was required to be made to the foundations or building.

III. Soham Mere, Dunn Gardner Estate.—This pumping plant, Fig. 4, was erected in 1910, and replaced an old beam-engine working with 10 pounds of steam, driving a 36-foot scoop-wheel. The engine is of the open compound type driving direct the centrifugal pump. The engine has cylinders 9 inches and 15 inches diameter by 9 inches stroke, and it is capable of developing 65 brake horse-power when running at 250 revolutions per minute, steam being supplied from a Lancashire boiler, 20 feet by 6 feet 3 inches diameter, at 120 pounds per square inch.

The diameter of the suction and delivery pipes is 22 inches and the pump is capable of delivering 35 tons of water per minute against a total lift of 17 feet. The condensing plant is of the ejector type capable of maintaining a vacuum of 26 inches. The injection water centrifugal pump is driven by belting from the main engine shaft, this water being carefully strained on the suction side.

The pump was placed in the old wheel-house and the suction and discharge pipes laid in the wheel race, no alteration whatever being made to the suction and delivery culverts. The engine stands in the old engine-house upon the old foundations, the foundation work being therefore reduced to a minimum. The coal burned is from 2½ to 3 tons in 24 hours. The main drain is about 20 feet wide and 6 feet deep at starting point, altogether 5 or 6 miles of drains connecting thereto, the discharge culvert being 6 feet by 4 feet 6 inches wide.

This district consists of about 2,000 acres and discharges its waters into Soham Lode about 4 miles above Ely. It was, as its name implies, an inland lake and was originally drained by windmills and the steam-driven scoop-wheel previously described. The strata of the soil consist of about 4 feet of silt, 3 to 4 feet of peat and then the clay. About 650 acres are held by small holders, the land, in quantities of 50 acres each holding, being let by the Cambridgeshire County Council.

IV. Martin's Farm, Hilgay.—This plant, erected in 1909, is one admirably suitable for landowners wishing to have, or compelled to have, their own drainage plant. It consists of an open double-acting single cylinder non-condensing engine driving direct a horizontal-spindle pump. The diameter of the cylinder is 10 inches with a 9-inch stroke, and when supplied with steam at 60 pounds

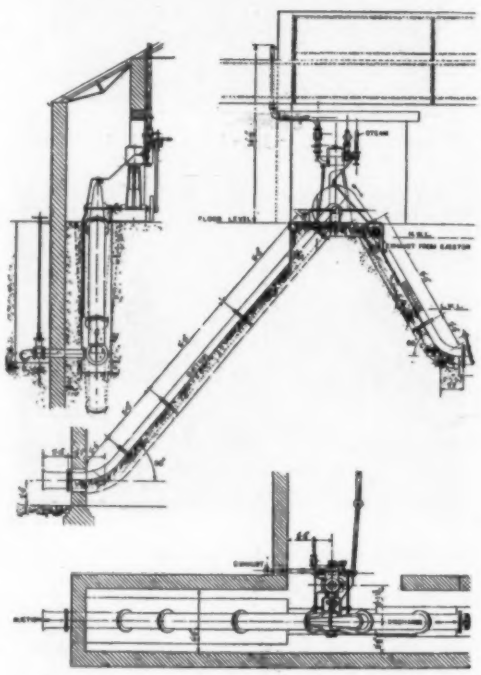


Fig. 5.—Mr. Martin's farm pumping station.

prevent siphoning back of the river water when the pump is not working. The boiler is 20 feet by 5 feet diameter.

This estate, which is situated in Hilgay Fen, discharges its water into the River Ouse about 5 miles above Denver sluice. The area is 750 to 800 acres, and was formerly drained by a single-cylinder beam-engine driving a 3[illegible] foot diameter scoop-wheel. Beyond deepening the su[illegible] tion and discharge culverts for a short distance, an[illegible] partially removing the division wall between the engine-house and wheel-house, no foundation work was neces[illegible] sary, the pump being placed on girders directly over th[illegible] old wheel race. Fig. 5 shows the arrangement of thi[illegible] plant.

V. Littleport and Downham District, Ten-Mile River Bank Pumping Station.—This installation, which is one of the largest drainage stations in the Fens, wa[illegible] erected in 1912. It consists of two double-acting open compound condensing engines driving direct horizontal-spindle high-efficiency centrifugal pumps. The engines have cylinders 14 inches and 22 inches diameter by 1[illegible] inches stroke, and are each capable of developing 20[illegible] brake horse-power with steam at a pressure of 120 pounds per square inch.

The diameter of the suction and delivery pipes is 4[illegible] inches, and the ends of the discharges are fitted with multiple flap valves. Each pump is capable of delivering 150 tons of water per minute upon a lift of 15 feet, or 190 tons of water per minute upon 10 feet lift, when running at a speed of 210 to 220 revolutions per minute; each pump is fitted with outside bearings and steam-ejector for charging purposes.

The condensing plant is of the jet type, each engine driving, through gearing enclosed in an oil bath, twin air-pumps, which run at 90 revolutions per minute. The diameter of each barrel is 8¾ inches diameter by 11 inches stroke, and they maintain a constant vacuum of 26 inches. The injection water is drawn from the main discharge culvert, passing through a twin strainer which can be cleaned without causing any cessation in the flow of the water. The air-pumps discharge into a hot-well, from which the feed-pumps draw their water. Steam is supplied by three Lancashire boilers, 25 feet by 7 feet 3 inches diameter, the feed water having its temperature raised by means of a live-steam heater. The pumping machinery, Fig. 6, is so arranged that each unit is quite independent of the other.

The following records of the working of these pumps have been kindly supplied by the officer of this district:

From October 30th, 1912, to April 9th, 1913, the total hours of running were 1,458. Total fuel consumed, 600 tons. Total average lift, 11 feet 8 inches. Total water discharged, approximately, 170 to 180 tons per minute. The main drain is about 23 feet wide, and in all approximately 26 miles of drains connect thereto. At starting point of pumping there is 6 feet of water in the drain, and at stopping it is lowered to about 2 feet.

This district has a taxable area of 26,000 acres, but a total area to be drained of 35,000 acres, which was originally carried out entirely by windmills. At present the whole area is drained by two pumping stations, 7 miles apart, one at the Hundred Foot River and the other at the Ten-Mile River. The first steam plant erected in the district was a 30 horse-power engine and scoop-wheel at the Ten-Mile River in 1818.

In 1829 an 80 horse-power beam-engine, having a cylinder 3 feet 6 inches diameter by 8 feet stroke driving a scoop-wheel 41 feet in diameter, was installed. This

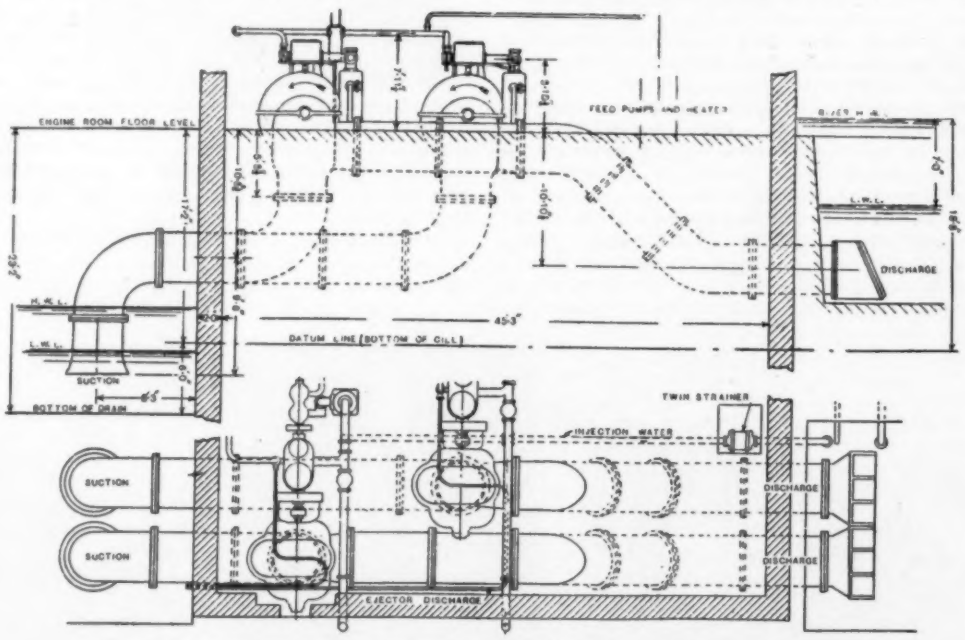


Fig. 6.—Littleport and Downham District. Ten Mile River pumping station.

wheel was, in 1882, increased to 50 feet diameter with 60 ladles, 8 feet long by 3 feet wide, and is working to-day. At the Ten-Mile River Bank Station, in 1843, the original steam-plant was removed, and an 80 horse-power condensing beam-engine was erected driving a scoop-wheel

42 feet 8 inches diameter, which was increased to 45 feet 8 inches diameter in 1880. The wheel had 50 scoops 7 feet 6 inches radial length by 3 feet wide, and made 4¼ revolutions per minute, the gearing being 7 of engine to 1 of wheel, and at that date had an average dip of the scoops of 3 feet. Owing to the subsidence of the land, this dip was gradually lowered to 1 foot 10 inches, and in 1912 this plant was removed, and the centrifugal pumps previously described were installed.

The rainfall recorded in this district since the year 1901 is as follows:

1901	14.81 inches.	1907	20.23 inches.
1902	17.86 "	1908	16.16 "
1903	27.65 "	1909	25.38 "
1904	16.85 "	1910	21.85 "
1905	18.87 "	1911	20.65 "
1906	21.32 "	1912	31.01 "

(*e*) *Horizontal Oil-engines driving horizontal-spindle Centrifugal Pumps.*—This class of machinery has been installed especially for small plants in several districts, the first to be erected being at Denver Parts in 1897, and consisting of a 9 brake horse-power oil-engine driving an 11-inch centrifugal pump. Mention should also be made of a 24-inch pump driven by a 40 brake horse-power oil-engine in the March Third district, and an 18-inch pump driven by a 40 brake horse-power engine at Willingham. The author understands that a plant capable of delivering 100 tons of water per minute has just been installed in the Methwold and Feltwell district. This type of machinery has not, however, met with as much support from the Fen Commissioners as was at one time anticipated, the efficiency for plants of large capacity having yet to be determined and the danger of fire being points which may have been the cause of the slowness of development in this direction. The interior and exterior of some of the pumping stations referred to are shown in the accompanying photographs in the hope that they may be of some interest.

In conclusion, the author ventures to express the opinion that at no time has the problem of efficient drainage of low lands been of more importance than it is to-day. The abnormal rainfall of 1912, and the amount of damage done to so many thousands of acres, has brought this important question more prominently before the Drainage Commissioners of the whole Fen District. That it is necessary to drain these lands more efficiently may be due to the increased difficulty of getting rid of the water owing to the constant subsidence of the land, and also to the fact that to-day a different class of produce is grown, in many cases vegetables of various kinds, in place of cereals. That pumping machinery of larger power and capacity are being installed is evident, but at the same time it is quite as essential that the drains leading to these pumps should be deepened and widened so that the water can reach them easily, as unless this is done the maximum efficiency of the pumping plants can never be obtained.

The Cost and the Advantages of Using Electrically Melted Ferromanganese*

ELECTRIC steel furnaces of various types have found a new field of application in recent years, as they are being widely used in Europe to keep a molten supply of ferromanganese on hand at the converter plant. The use of molten ferromanganese instead of solid ferromanganese not only results in a saving of alloy, but makes the deoxidation more efficient and the steel better; and the cost of melting the ferromanganese electrically is more than counterbalanced by these advantages.

This method has been widely introduced during the last few years in Europe. The first plant to take up this practice in this country has been the Illinois Steel Company, which at its converter plant at Joliet, Ill., employs a 4-ton Heroult furnace to keep on hand a supply of molten ferromanganese from which 150 pounds are taken every seven minutes. It is the experience of this company that besides the saving in alloy there is a clear advantage in quality, the soft steel produced being decidedly better for wire purposes.

In Europe various types of electric furnaces have been employed for the same purpose, and the induction furnace has found particular favor in several plants. As very few exact figures have been published in the past on this subject, the following results obtained in three European plants employing induction furnaces for melting ferromanganese should be of timely interest:

The three plants in question use for this purpose a 3-ton, 350-kilowatt furnace, a 4-ton, 500-kilowatt furnace, and a 4-ton, 500-kilowatt furnace respectively, all being of the 3-phase, 50-period, 3-ring Roechling-Rodenhauser type, the design of which is very well known to our readers.

In the plant using the 3-ton, 350-kilowatt ferromanganese-melting furnace, some 30 to 50 tappings, ranging each from 90 to 120 kilogrammes (198 to 264 pounds), are made every 24 hours, depending upon the demands of the steel plant. For the first five weeks the average energy consumption, excluding the energy required for burning in the lining, was 721 kilowatt-hours per ton for an output of 220 tons of ferromanganese.

To maintain the furnace hot during long intermissions 200 to 250 kilowatts are required.

As a result of using molten ferromanganese, an average saving of 30 to 40 per cent of weight of ferromanganese required is recorded. With cold ferromanganese from 7 to 8 kilogrammes are used per ton of steel, and during a year some 2,100 tons of cold ferromanganese are required. With molten ferromanganese this amount is reduced to less than 1,400 tons, representing a saving of more than 700 tons, which at $55 per ton represents a saving of $38,500 per year.

In one of the plants with a 4-ton, 500-kilowatt furnace ferromanganese has been melted at the rate of 10 tons per 24 hours with an energy consumption of 750 kilowatt-hours per ton. The furnace, however, is capable of melting a considerably higher tonnage of ferromanganese per day, and when the demand of the steel works increases it may be expected that the specific energy consumption will be reduced.

At the same time the amount of ferromanganese used per ton of steel has been reduced at this plant from 7.5 or 8 kilogrammes (for cold metal) to 4 kilogrammes (for molten metal), which is a saving of from 45 to 50 per cent.

If the results of these two furnaces are used on which to base an estimate of the power requirement and savings to be expected in new installations, it seems safe to figure on a saving of 30 per cent in weight of ferromanganese and a power consumption of 675 kilowatt-hours per metric ton of ferromanganese for a 3-ton furnace in regular operation. For burning in the lining and heating up a 3-ton furnace about 3,500 kilowatt-hours are required, and a life of 12 weeks, or 84 days of 24 hours, may be expected for the lining. From these data a figure for an additional small power consumption may be deduced. As stated, all these figures refer to induction furnaces. It would be interesting to get for comparison data from arc-furnace installations.

* Reproduced from *Metallurgical and Chemical Engineering.*

Electric furnace for melting ferromanganese at Krupp plant.

The use of molten ferromanganese has, however, additional advantages which cannot be stated as easily in figures. Owing to the rapidity with which molten ferromanganese becomes distributed through a steel charge, much time is saved owing to the fact that the steel may be teemed at once. Further, low-grade ferromanganese, containing large percentages of fines, may be easily melted in an electric induction furnace.

That the quality of the steel is improved by the use of molten ferromanganese will be understood from the following considerations:

The deoxidizing effect is much stronger and more rapid than with solid ferromanganese, as the latter must first be dissolved and exerts a certain cooling effect.

As the ferromanganese is added to the steel while teeming, it does not come into contact with the slag, and rephosphorization by reduction of the phosphates in the slag is entirely excluded.

Frequent analyses in the three induction furnace installations in question have proved that the composition of the steel remains constant from the first to the last ingot for any one charge.

On account of the uniformity of the composition of each ingot, due to the better distribution of manganese and also to the more complete deoxidation, the steel "rolls" extremely well. It has been proven that a section which, when cold ferromanganese was used, could not be satisfactorily rolled with steel containing less than 0.4 per cent Mn, can, when molten ferromanganese is used, be rolled easily from steel containing only 0.29 per cent Mn.

The amount of ferromanganese per ton of steel can be considerably reduced on account of the certainty that the total amount of ferromanganese added is utilized and nothing is retained in the slag or remains undissolved in the steel.

The contents of the ladle can be poured at once, whereas much time is saved, and, moreover, the charge need not be so hot from start so as to be able to heat the ferromanganese to melting temperature. The liquid steel remains completely quiet, does not boil, and can be poured very satisfactorily.

The lining is put into ferromanganese induction furnaces in about the same way as in steel furnaces; that is, a mixture of magnesite, or dolomite, with tar is rammed in hot. But because the temperature required is not so high as for steel, and also because ferromanganese is usually in particularly convenient form for melting in an induction furnace, the life of the lining is much prolonged. From the results so far obtained it is thought possible when working continuously to average between four and five renewals per year, or even better.

No slag is required. The molten metal is effectively protected from oxidation by a layer of carbon in the form of petroleum coke. The metal being saturated with carbon, no alteration in composition occurs. The fact that such a covering is used proves that the atmosphere in the furnace is non-oxidizing.

While, as stated before, the Roechling-Rodenhauser type of combination induction furnace is used in the three installations here discussed, the Siemens & Halske Company, which made these installations, has developed more recently an improved type of induction furnace which combines the good points of the Kjellin, Roechling-Rodenhauser, and Frick types, and with which it has been possible to reduce the specific energy consumption still further.

While the data given above from European practice refer to plants using induction furnaces for melting ferromanganese, other types of electric furnaces are also used for this purpose in Europe. The adjoining illustrations show a 5-ton Girod furnace recently installed by the Friedrich Krupp A. G., Friedrich-Alfred Hütte, Rheinhausen-Friemersheim, Germany, for the melting of ferromanganese.

The "Day of Rest" and Human Efficiency.

THE refreshing influence of the weekly "day of rest" on a person subjected to the strenuous routine of a busy life is a feature which he himself can duly appreciate in the effects on his "feelings" and "spirits." The efficiency of the working-man, the length of the working-day, the interjection of pauses for rest in the schedule of labor for persons of different ages and stations in life—questions of this sort are constantly arising for solution on a scientific basis. Not only in the field of manual labor, but also in the case of the schoolchild, the office-boy, the factory-girl, the banker and the merchant, efficiency is the key-note of the times.

In view of this, says *The Journal of the American Medical Association*, it is of more than passing interest to know that Dr. Martin and some of his associates in the Laboratory of Physiology at the Harvard Medical School, have been making a careful study of the whole question of fatigue and efficiency from a physiological standpoint. A long series of experiments have been made on first-year medical students who were following a regular routine of school work during six days of each week. The routine was interrupted weekly by the Sunday recess, an interval occupied variously by the students, but in no case in precisely the manner of the week days. The daily observations made on these persons during several weeks show that at the beginning of the week the nerve reaction tends to be high, that from then until the end of the week there is a fairly continuous decline, and that following the interruption of the routine by the intervention of Sunday, it returns to the original high point.

The decline is interpreted as a cumulative result of general fatigue incident to routine. What is even more significant, however, is the added fact that a pronounced break in the routine—such as the "day of rest" occasions—may bring about a return of sensitiveness to a high point or, in other words, it restores the nervous tone. Studies continued in this direction should lead to some useful conclusions regarding the maximum of work, with respect to both its duration and type, that should determine the conditions under which the organism of man may be maintained without depletion.

Safety at Sea

Provisions for Averting Loss of Life

THE development of our great passenger steamers in point of size, speed and luxuriousness, has for many years past followed an upward curve, the crest of which has not yet been reached. Unfortunately a parallel progress in the matter of safety cannot be recorded. In fact, in one sense, it might be said that dangers of sea traveling have increased. For the larger the boat, the greater is apt to be the list of casualties in case of serious accident. This is not a mere academic argument, but a truth only too plainly demonstrated by the events of the past few years. Tragedies like those of the "Slocum" disaster, the sinking of the "Titanic," and quite recently, of the "Empress of Ireland," leave indelible memories in people's minds—a psychological effect upon millions of people. It is well that this should be so; it is merely one expression of the natural instinct which bids us profit by experience. But to what extent can this instinct be said to have worked effectively in the matter of safety at sea? Recent events hardly seem to warrant any optimistic view on this point. True, the very fact that disaster has followed so close upon disaster has given naval constructors little chance to make any material advances. It can hardly be expected that a large number of existing ships be radically reconstructed to meet the requirements, now recognized, of the maximum attainable degree of safety. Yet there are indications that the lesson of the "Titanic" has not yet been fully assimilated, and it seems to have required this renewed disaster to force home the necessity of the double skin in those great steamers that carry thousands of passengers.

There can be no doubt that the chief attention of the naval constructor, as regards provision for safety of travel, must be concentrated upon the prevention of disaster, rather than upon those poor last resources, lifeboats, etc., which have proved so inadequate in all great shipwrecks.

Nevertheless it will never be possible to dispense entirely with these accessories, and efforts to make them as perfect as possible are entirely in order. The provision of various substitutes or partial substitutes for the customary lifeboats has been suggested. The motor-driven lifeboat commends itself as a modern improvement, but has not yet proven its worth. Moreover, its use is presumably limited, since it is hardly likely that all a ship's lifeboats can ever be thus equipped. Rafts of various kinds have been suggested and actually installed. Soon after the "Titanic" disaster, we published a description of a "floating deck," which should be released from the body of the ship in case of the latter's sinking, and which should remain afloat and provide a safe refuge for the passengers and crew until they were taken off by some rescuing vessel.

That there is merit in the proposal, and that it can be practically applied, is shown by the fact that the Pollok prize for the best method of saving life at sea was awarded to a design in which the whole of the bridge structure was so built that it would float independently of the vessel.

It has been suggested that, in the case of a ship like the "Titanic," the large deck houses on the boat deck might be built upon this principle and so arranged that they could either be launched from special launching ways, or permitted to float free when they become sufficiently submerged to assert their buoyancy.

The objections to this arrangement are: First, that such structures would be too heavy to be launched in an emergency with any certainty of safe and successful operation; and secondly, that if the pontoons were left to float of themselves as the ship went down, they would be liable to become entangled with the smoke-stacks and their heavy steel guy ropes and either upset or seriously damaged. In nine cases out of ten, the damage to ships is received forward of midships, and the vessel sinks by the head. Evidently, then, the best location for the pontoon structure would be at the stern of the ship, and preferably on the quarter deck.

We reproduce, from an earlier issue of the SCIENTIFIC AMERICAN, on our front page, the outlines of a design in which the upper decks of the after portion of the ship, astern of the midship structure, are utilized for this purpose. In the design shown, the pontoon extends for a depth of two decks, covers the full width of the ship, and reaches from the midship superstructure to the after-rail. For full security, and to provide the necessary stiffness, it might be built with a shallow double bottom. The outside hull plating might be carried down until it lapped, with ample clearance, an inch or so over the plating of the ship itself—an arrangement which would conceal the fact that the pontoon was a separate structure and would give it the appearance of being an integral part of the ship itself.

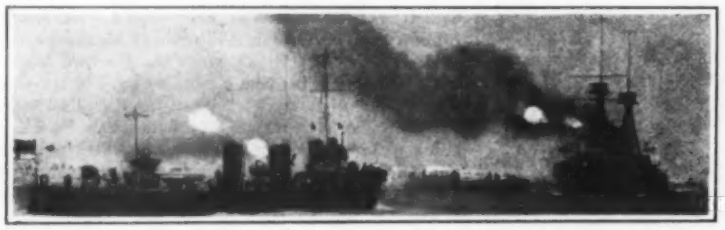
The problem of securing this pontoon in place would not be so difficult as might be supposed. It could be done

Whistle-blast signals and their meanings.

Drawn by Cecil King, R.B.A.

One short blast.—"I am directing my course to starboard." The two vessels are approaching end on; each is going slightly to starboard, and they will pass to port.

Three short blasts.—"My engines are going full speed astern." The vessel on the left has the right of way, and is holding on and going slightly to starboard (one blast); that on the right is going full speed astern. (Compare also the illustration opposite.)



Two short blasts.—"I am directing my course to port." The battle-cruiser is coming out of harbor and crossing over to port; the destroyer is going to port also.

Two long blasts.—Blown in thick weather by a vessel under way but stopped, and having no way upon her.

Lights and the rule of the road for ships.

"Green to green and red to red;
Perfect safety—go ahead."

Each ship is showing the other her port light.

"If to your starboard red appear
It is your duty to keep clear . . . .
If green to port there's nought to do,
For green to port keeps clear of you."

The left-hand ship *shows* a green light, but *sees* the red light of the right-hand ship on her starboard hand. The former must therefore give way.

Sailing.—A ship close-hauled on the port tack gives way to one close-hauled on the starboard tack. Here the right-hand ship gives way.

A steamer always gives way to a sailing-ship, whatever her course.

n several ways. As a suggestion, the deck on which it ested might be provided with several longitudinal rib-ike projections which would register with corresponding ongitudinal recesses, sunk in the outer shell of the double ottom of the pontoon. Both the ribs and the recesses would be tapered in cross section, and both would be provided with bearing strips of bronze or other non-corrodible metal, so as to insure the ready release of the pontoon when the ship went down. These ribs would effectually hold the great weight of the pontoon against lateral movement when the ship was rolling, and the friction of the ribs would be sufficient to prevent longitudinal movement under the much smaller fore-and-aft forces set up by the pitching of the vessel.

If it were deemed necessary, a few holding-down bolts, readily accessible and quickly released, might be added as a further precaution. A double-deck pontoon, with its deck houses of the size shown in our front page engraving, would be sufficient to accommodate, in an emergency, the whole of the passengers and crew of one of our modern leviathans.

In connection with the collision between the "Empress of Ireland" and the "Storstad" questions of right of way at sea and methods of signaling, especially at close quarters and in fog, have been brought before public attention. The accompanying illustrations, for which we are indebted to the *Illustrated London News*, show graphically some of the signals by whistle or siren, and also some of the ships' light signals referred to at the inquest at Rimousky. Capt. Kendall in his evidence said: "I blew three short blasts on the steamer's whistle, meaning, 'I am going full-speed astern.' After that he answered me with his whistle, giving one prolonged blast. I then looked over the side of my ship into the water and saw that my ship was stopped. I stopped the engines and blew two long blasts, meaning that my ship was under way, but had stopped and had no way upon her. . . ." With regard to the last signal, it may be noted that in the Regulations for Preventing Collisions at Sea is the notice: "A vessel is 'under way' within the meaning of these Rules, when she is not at anchor, or made fast to the shore or ground." It is prescribed that steam-vessels shall give sound signals on the whistle or siren. The words "prolonged blast" mean a blast of from four to six second's duration. The words "short blast" mean a blast of about one second's duration.

In the statement made for the captain of the "Storstad," it is said: "The vessels sighted one another when far apart. The 'Empress of Ireland' was seen off the port bow of the 'Storstad.' The green (starboard) light of the 'Empress of Ireland' was visible to those on board the 'Storstad.' Under these circumstances the rules of navigation gave to the 'Storstad' the right of way. The heading of the 'Empress of Ireland' was then changed. . . . Shortly after, the fog enveloped first the 'Empress of Ireland' and then the 'Storstad.' . . . . The 'Empress of Ireland' was then seen through the fog close at hand on the port bow of the 'Storstad.' She was showing a green light and making considerable headway." A regulation of the sea says: "When two steam vessels are meeting end on, or nearly end on, so as to involve risk of collision, each shall alter her course to starboard, so that each may pass on the port side of the other."

The Future of the Submarine

KEEN interest has been reawakened in England in the subject of the relative importance of the submarine-boat and the battleship by the publication in the London *Times* of a letter from Admiral Sir Percy Scott, because this distinguished naval officer has taken the view that the "building of any more battleships now will be a misuse of money subscribed by the citizens for the defence of the Empire," as he can see "no use for battleships and very little chance of much employment for fast cruisers." Commenting upon this, our British contemporary *Engineering* remarks: "For a long time it has been recognized that the submarine-boat must take an increasingly important part in war tactics, and there is no doubt that in those peace maneuvers where war conditions are simulated the submarine-boat has taken a place of growing significance and success. But the storm of criticism which Sir Percy has raised in the columns of our contemporary shows that the change he advocates now must be of gradual growth, and not a *volteface*, and that the acceptance of his view, as quoted, would be a grave danger to the defence of the empire. It certainly cannot be said that he has adduced convincing reasons for the complete change in naval policy which he advocates.

"His view is that at the beginning of hostilities submarine-boats will be able effectually to bottle up in harbors all surface craft, and that a 'battleship is not immune from attack even in a closed harbor, for the so-called protecting boom at the entrance can easily be blown away.' Thus, if a battleship is not safe on the high seas or in harbor, he asks: 'What is the use of a battleship?' Moreover, he says, submarine-boats are difficult to destroy, because 'it is difficult to attack what you cannot see.' Thus he contends that what we require is an enormous fleet of submarines, airships and aeroplanes, and a few fast cruisers, provided we can find a place to keep the latter in safety during war time. We are at one with Sir Percy Scott in his view that we should have a great fleet of submarine-boats, but until other powers decide to cease building battleships and other surface craft, it would be fatal for Britain to discontinue the present policy so far as these are concerned. A 'Naval Officer,' who has written most cogently on the weaknesses of Sir Percy Scott's contention that we must cease building battleships, controverts the premise on which Sir Percy founds his conclusion. The booms protecting harbors have never been destroyed by submarine-boats, and although torpedo-boat destroyers have been able to enter harbors thus protected, they have done so by 'jumping the boom,' with considerable damage to themselves. Moreover, if the enemy's surface ships succeeded in escaping from harbor, there would be serious menace to Britain, and particularly to our food supply, in consequence of the depredations which they might effect when unopposed by vessels of equal modernity and corresponding speed. No doubt for a few years our present surface boats would equal in tactical quality those of the enemy. But if, at Sir Percy Scott's injunction, we ceased building such vessels, while other powers continued to do so, we should be placed in jeopardy in a very short time. It may not be easy to fight submarine-boats except by their opposites; but by reason of their comparatively low speed, they would never overtake a surface boat which might escape from harbor. Besides, it has not been established by Sir Percy Scott that the torpedo, practically the only weapon of the submarine-boat, would be effective. Again, the radius of action of such boats when submerged is very limited, not much more than 100 miles, so that in taking a voyage across the North Sea they would have to proceed 'awash,' and would then be subject to attack by torpedo-boat destroyers and other surface craft, and by aerial vessels.

"Our intention in discussing this matter is not so much to consider the tactical qualities, but to regard the problem of the future potentialities of the submarine-boat from a mechanical standpoint. Until such craft are made more powerful, are given a higher speed, and have a much greater radius of action, their success must be limited, even in attacking vessels in harbor, particularly in the presence of the latest system of submarine-mine defence. All of these qualities call for increased dimensions, which increase their cost and reduce their handiness, especially in harbors and comparatively shallow waters. That progress is being made in the design of submarine-boats to attain the advantages desiderated is undoubted. The British Admiralty are fully alive to the possibilities of this new type of craft. They are vigilant in their study of progress in other navies, and are acting with enterprise in the encouragement of developments, particularly in respect of propelling machinery and torpedo design. The interests of the nation preclude us from giving information regarding the latest British experimental vessels, but it may be said that in the one case the size exceeds that of any submarine-boat yet ordered, and that in another case the aim is for higher speed. When these two vessels are completed their trials will disclose to the technical officers of the admiralty the lines along which further development may be made.

"First, in regard to size, it may be said that the largest of the German boats nearing completion has a displacement on the surface of 750 metric tons, and submerged of 900 tons, the length being just over 214 feet. It is propelled by two sets of Diesel engines, together of 4,000 brake horse-power, working twin screws, and it is anticipated that the speed on the surface will be about 20 knots, and submerged about 10 knots. Russia is understood to be building a vessel of considerably over 1,000 tons, and proposals for ships of as much as 1,700 and 2,000 tons displacement are being considered by other powers. These larger vessels will be able, of course, to carry a greater offensive armament, either by increasing the number of torpedoes, or by fitting larger guns with disappearing carriages, for which cavities are formed in the deck. It is understood that, so far, only 12-pounder guns are contemplated. If, however, four guns of 4-inch caliber were adopted, the displacement would require to be increased, while the adoption of 6-inch guns would necessitate an increase in displacement of 18 per cent over the vessel with 12-pounder guns. Increase in size, too, demands greater power, even if the speed be constant, and the aim is to get still higher speeds. So far practically all modern submarines are propelled by heavy-oil engines, and little difficulty need be experienced in supplying to a submarine-boat engines of 4,000 or 6,000 horse-power without increasing to any appreciable extent the size of the individual cylinder. Moreover, progress has undoubtedly been made in the reliability of engines with cylinders of much higher power, and one may anticipate in the early future cylinders of 1,000 horse-power. No trouble need be anticipated on this score excepting that the size of the ship must go on increasing if higher speeds are desired than are at present anticipated.

"There is, however, a growing disposition to experiment with steam-turbines in submarine-boats, and it will be remembered that France many years ago adopted a flash boiler for developing steam for driving submarine-boats, but the results were such that the system was discontinued, largely because of the time required to damp down the boiler preparatory to diving. With the perfection of oil-fuel-burning apparatus for water-tube boilers, and the great gain in the introduction of the steam-turbine, opinion in France has undergone a change, and at the present time there are being built a large number of submarine-boats, with express boilers of the Yarrow type, having specially small tubes, in order that the water contents may be less than is the case even with destroyers. The turbines are of the Parsons type, to run at very high speed, gearing being introduced between the turbines and propellers. The four submarine-boats of this type most advanced are those built at Rochefort, of 900 tons displacement, and with turbines to give 4,000 shaft horse-power, namely, 2,000 on each shaft. Two others are building at Cherbourg, and in this case the displacement is 950 tons, the power being 5,000 shaft horse-power. There will be electric motors for propulsion when submerged, as in existing vessels. It is understood that even larger steam-driven submarines are about to be laid down, the power of the turbine machinery being 10,000 shaft horse-power, and the speed anticipated over 20 knots. It is under consideration in this latter case to fit, for low-speed running, oil engines for cruising on the surface. This would conserve the oil-fuel supply, as the oil engine has a less consumption than the steam installation. Thus the radius of action at cruising speed would be very greatly increased. It is a case of balancing advantages and disadvantages from the weight point of view. It remains to be seen whether the oil engines for cruising at low speed would save, under given strategic conditions, an amount of fuel corresponding to the excess consumption at low speed of the steam engine, and thus compensate for the weight of the oil engine, which must be dead-load when running at full speed. But there still remains the fact that greater power of offensive, higher speed, and wider radius of action—all necessities of the case—involve increase in size.

"Every increase in the size of a submarine-boat not only adds to its visibility when running awash, but increases the time and distance required for disappearing if the vessel has to dive, and not to sink on an even keel, unless the angle at which the vessel dives is made much steeper. The difficulty in such case has reference to the electric storage batteries, and to other vessels containing liquids, where alterations in the level introduce disturbing influences. The acuteness of the angle of dive, too, intensifies the difficulty of subsequently bringing the vessel to an even keel, and increases the danger of the vessel striking the bottom, a danger which has involved the loss of one or two submarine-boats of comparatively small size. Greater depth of water is required for such operations, so that only small vessels can be used in attacking ships in harbor.

"These various developments in the mechanics of the submarine show that progress is being made, but the problems have so many variants and demand such careful research that it would be a mistake to hasten unduly those responsible for the evolution of design. What is demanded on the part of our naval authorities is to move with as much rapidity toward improvement as is consistent with the insurance of reliability in each vessel built, and at the same time to maintain as much secrecy as possible. From the mechanical point of view the submarine is undoubtedly in a transitory state. To accept any design at the moment, and build a great number of vessels in excess of the requirements as measured by our opposing forces, would be unduly to tax the citizens' responsibility for the defence of the empire, with the extreme probability that the vessels thus built would be obsolete in a very short time. For this reason we advocate an active policy by the admiralty, but would regard as a tactical blunder the neglecting of the building of ships-of-the-line, particularly when all other powers are continuing to add to their fleets battleships and cruisers."

Hyndman Peak, Idaho, the highest named peak in the State, is more than 12,000 feet high. Several unnamed peaks near it are of about the same elevation. All are on the divide between the Sawtooth and the Lemhi national forests.

How the Ancients Would Have Controlled the Mississippi and Its Tributaries*

By Sir William Willcocks, Cairo, Egypt

WHEN I went to South Africa for the British government about ten years ago I remember being asked to address a number of Boer farmers on the question of rust, which had attacked their wheat crops. After describing to them how the Egyptians had for 7,000 years sown wheat and leguminous crops in rotation, and at the end of those 7,000 years had their land as rich as it was when they first began, while the Boers in 50 years by growing cereals only had made their land so poor they could scarcely get anything to grow on it, I thought I had made an impression on those people; but when I had finished, the chairman said to me: "Now don't talk to us about those exploded old world theories of rotation of crops. We young people have altogether grown out of that." My discourse on that occasion was fruitless. I hope for different things from you.

With your permission I am going to tell you how I think the ancients would have controlled the Mississippi River and the flood problems you have in this country. The problems on the Mississippi are harder than those on the Nile. They are like those on the Euphrates, but the Tigris is more difficult. In Egypt they began reclaiming the delta from upstream downward. When they had reclaimed a certain part they let the water flow on and reclaimed another, and so on. That was a simple problem. On the Euphrates and Tigris they began from the mouth upward, as you have done on the Mississippi.

I find that the Mississippi is about four times the size of the Nile, seven times the size of the Tigris, and twelve times the size of the Euphrates. But size in these questions has nothing to do with difficulty. Indeed, I have always found in any problems I have had to do with, that the bigger the problem the more easy it was to solve. You can see a big problem so clearly and its difficulties lie patent. I have always considered that a thing like the Assuan dam with 180 openings is less of a problem than a dam or a bridge with only one opening, because if one fails, and you have only one, the whole thing fails; but if you have 180 and one or two fail you have still 178. And to bring it home to all of us, I am sure there is not a single married man among us who does not know that Solomon with his 300 wives had a much easier problem than any of us has with his one wife.

The ancients were always very much in earnest with their rivers, far more so than you are here. In this country the lands likely to be inundated by the rivers lie here and there scattered over the face of the country. But in Egypt and ancient Babylonia they had nothing but what was irrigated by their rivers and able to be inundated by them. Everything else was desert. Imagine for an instant the Senators and Representatives in Washington sitting down and looking academically at the question of the Mississippi River levees, if the Capitol itself were located behind one of the levees of the Yazoo basin. Or imagine, as you have here, the commission which looks after the Mississippi levees taking care to locate itself well up at St. Louis, where it is totally out of danger. In Babylonia we should have made them all live behind the worst of their levees, and whatever else they did they would not have had any breaches. I believe you call them crevasses; we call them breaches. Accidents happened on the Mississippi in 1912 and millions of acres were inundated, 4,000,000—the whole of Egypt is only 6,000,000—and little thought was taken of it in this country. In the seventh century of our era a very serious breach occurred in the Tigris levee, and the King on that occasion threw 400 engineers and supervisors into the breach.

In 1887, when we had our last very high flood on the Nile, I saw a white-haired man going about his work very energetically, and I said to him, "I have never seen an old man as energetic as you." He said, "I am not old, only my hair is gray." I said, "How did it become gray?" He said, "I had charge of the Nile bank in the great breach of 1878. When it occurred the Khedive telegraphed to throw the engineer into the breach. I was that unfortunate man. They did not throw me in because the telegram arrived at evening, and they said they would do it at daybreak. My wife and other members of my family went up on special train to implore the Khedive to let me off. And in the morning I found that my hair had grown absolutely gray."

The Mississippi has been reclaimed, unfortunately for itself, from the mouth up. Louisiana made for itself fields and gardens behind its levees. When the next State farther up the river made its levees and concentrated the flow, it put Louisiana into difficulties. Louisiana raised its levees, and then it went easier until the next State up stream started to build levees. And however hard Louisiana works, it can barely keep ahead of the difficulties brought on it.

That is exactly what happened in Noah's flood. There was no Noah's flood in Egypt, because in making their river control works, they came down with the river. On the Euphrates they traveled up, and it was a very large dike thrown up to protect some upper basin which threw the whole waters of the river on those lower down, which produced the catastrophe known as Noah's flood.

The Mississippi from Cairo to the sea has a length of 1,000 miles; in a straight line it is 550 miles, and the width of the valley is about 50 miles. The fall in flood is 320 feet and in low water 270 feet; 1,540 miles of levees are along its banks. (In Egypt we have about 900 miles of levees.) The salient points, where the Mississippi bends from side to side, need protection and cover 400 miles. The *natural reservoirs* in the Mississippi Valley, which I shall call *basins* to distinguish them from reservoirs which are proposed in the hills, cover a very large area. The St. Francis basin with 4,000,000 acres, the Yazoo with 4,000,000, the Tensas with 3,000,000, and smaller reservoirs on the sides, bring the total above the Red River to 12,500,000 acres. Down stream from the Red River are 6,500,000 acres. These give altogether 19,000,000 acres of natural reservoirs.

Like all deltaic river valleys, that of the Mississippi is highest near the river bank, and slopes away to the hills on either side. In places the water at the bank is 30 feet higher than at the hills, so that when the water makes a breach it has plenty of land to go over, and finds it very easy to get away. Then this river, like all deltaic rivers, brings down a great deal of sediment. But the river soon begins to drop this into its bed, and then cuts out from the sides at the bends. Low down in its course nearly the whole of the sediment in the river is that which the river itself is cutting from its own banks.

Allowing six feet of water above the natural bank of the river, which is where the flood of 1882 came to, I calculate that these natural basins, or reservoirs, in the Mississippi Valley itself represent about 12,500,000 acres, eight feet deep, or 100,000,000 acre feet. I have put these figures into acre feet because left in cubic feet they run into nine or ten naughts, which represent things we do not understand.

Now if the ancients had had this river, they would have considered these reservoirs as a great asset, and never would have used them or let them be cut by levees until they were quite sure that all the lands below were well protected against inundation. As the first lands to be reclaimed were in Louisiana, the next basin above it is the Tensas. They would have done one of two things. They would have either run the levee down one half the length of the Tensas, letting the other half be flooded, or they would have taken half the basin in the length of the river and surrounded it with levees, and let the river go around the other half. But they would not have allowed a levee to be put up until the lower ones had been strengthened. Having done that and allowed eight or ten years for the river to adjust itself to the new conditions, they would have gone to the next basin, the Yazoo, and taken half of it and treated it in the same way, previously protecting all the levees below. Then in thirty or forty years they would have gone to the next, the St. Francis, and taken half and treated it the same way, taking care that everything from there downward was well above the level of any possible flood.

As this operation went on and the waters were cut off from overflowing the basins and kept within the channel, the river would gradually have widened, and may be deepened itself, to meet the new conditions. It would have needed time for that, but you people in this country give nothing time, and the Mississippi River has had no time to do anything in all the operations that have been performed on it. Every time a breach or crevasse occurs in a levee the river down stream for 50 or 60 miles is totally disorganized and all the good done in previous years is thrown away, and the work of making the channel suit its new conditions has to be done again. If it had been done in the way the ancients did, the Mississippi, with its 19,000,000 acres of valley, would have had 9,000,000 acres thoroughly reclaimed, and 10,000,000 acres still covered with water in flood time—and being greatly improved with the mud deposited on them.

Acting in a way different from this, and letting everyone do that which was good in his own eyes, no more than about 4,000,000 acres have been reclaimed, instead of 9,000,000, and much of it indifferently, while the primeval forest covers by far the larger part of the land.

Some may say that this is purely an academic discussion. This is what the ancients would have done. Now, the question before us is with the river as it is; supposing the ancient engineers came into this valley as it is to-day, what would they have done with it? I will first describe what the Mississippi Valley is to-day. If you go down from Cairo, the first basin on the right bank is the St. Francis, with 4,000,000 acres, and it has a levee along almost its entire length. The Yazoo basin of 4,000,000 acres on the left has a levee along almost its entire length. On the right bank the Tensas with 3,000,000 acres has the same; and from the Red River on, both banks have levees past New Orleans to the sea. The small basins are unprotected.

I will lay down a few propositions. Before a basin like the St. Francis is allowed to have a levee, from the end of that levee downward, calculations should be made and the height of the flood which is going to be artificially produced by that levee, calculated. Then profiles of levees 5 feet above flood should be put up, 10 feet wide, every 10 miles all the way down the river, so that every man could see for himself the terrible condition that is coming.

If, for example, the Mississippi when in its banks, discharges 1,000,000 cubic feet a second with a velocity of 6 feet it has worked out for itself, owing to the kind of soil which it has in its valley—and a very poor and bad soil it is to resist the current—it has cut out for itself a channel 5,000 feet wide and 33 feet deep. If you put the whole discharge of 2,000,000 feet a second, that passes Cairo, into the stream it would begin by having a depth of 48 feet or it would rise 15 feet at once, and with its width still 5,000 feet, a velocity of 8 feet a second, which is a great increase. It would undoubtedly begin to widen itself. This river has a width which is 150 times its natural depth, so that when you increase its depth by 15 feet it would want to increase its width by over 2,000 feet. But as it increases its width by every 10 or 11 feet, the section increases and its depth falls. With water which is wonderful in its adjustment, the stream would adjust itself, and in time, if left alone to work out its own salvation, it would become a river about 6,500 feet wide and say 40 feet deep. And so gradually working in this way, you would have got your river only 7 feet above its banks in highest flood. But working suddenly and raising suddenly is not engineering.

More important even than the levees as the river sweeps around its bends in its valley are the protective works at its sides. This protection is very well done in this country. Not enough is done to keep pace with the requirements of the river, but what is done is well done. The river, instead of tearing down its banks in poor soil, is fixed by matting and stone, as though it was flowing between hills. With these protective works I consider that, if the river in its natural soil can run 6 feet a second without difficulty, it could take 7 feet quite easily if well protected. Now, in this country there is no nervousness in raising the water 15 feet in height and increasing the velocity from 6 feet to 8 feet, but the extra velocity that would come from these great bends being cut across to make the channel shorter has occasioned extraordinary nervousness. Yet of the two, as I see it, this is the less dangerous. If you increase the velocity from 6 to 8 feet, that velocity goes clear down the whole river; but if you cut off a bend and increase the velocity at any point, you immediately decrease the depth, and this has a wonderful way of adjusting itself. This I have seen for myself. But if you let a cut-off take place in a high flood when the river is full and velocity very great, you court an enormous amount of damage. Such things the ancients would have done just after the flood. They would have cut it so that the river would have had eight or nine months to flow under its new conditions, and when the next flood came it would not have been very serious, as the river had adjusted itself to its channel. For in all such rivers, if you can get the low water supply to flow in any channel, and it is happy in that channel, the flood will follow it without any difficulty. I assume that the

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salient bends are well protected with mattresses and stone in your best style. Well burnt, huge bricks of the Babylonian type might be cheaper and better than stone. Great monoliths might be fused in this way.

Where the levee is far away from the mattress protections it might pay to protect only 1,000 feet per mile and let the river bite into its banks between these fixed points. There would be a limit to the biting action, and a million dollars might go as far as three million would go if you protected every inch. It is worth trying where the levees are far back.

It is often said that the river Theiss, in Hungary, was a winding river, and they cut off the bends with the result that the water swept down the valley and destroyed the towns and lands lower down. But that was very foolishly done. If instead of beginning at the source and cutting 10 or 12 bends off at once, they had begun from the bottom, or mouth of the river, and worked upward, cutting off one a year, they would have had none of those difficulties, and the citation of this river as a type of that kind of work is not an accurate thing. It was a very badly managed job.

When once a river has accustomed itself to a new channel we know from the river Nile, whose records go back 5,000 years, that streams like these raise themselves gradually on their beds very slowly. The Nile Valley rises about 5 inches in 100 years. (The Euphrates has risen about 1½ feet.) So steady is this rise that to-day if you dig down 24 feet in the Nile Valley and find the foundations of a building you can calculate the number of years at 5 inches for every 100 years, and you can say B. C. 4,000 or 5,000, or whatever it may be, this building was built here. And when you dig it up and find the remains you are nearly always right, as the rise has been steady through all the centuries. And although no records of this kind go back in Babylonia, yet the same thing is true, because the foundations of the different buildings in different ages and the different facts recorded all bear witness to this steadiness of rise of the country.

Now I repeat that of all the things you do on the river, the first and most important is to protect the cutting of the banks at the salient bends; because when you increase the velocity and change the river from what it was, the thing to do is to fix the points within which it must flow. While it wanders inside those limits, it does not matter what it does.

I have considered this problem only to the Atchafalaya Escape at the Red River, because below this there need be no difference. This is a very efficient escape which goes into the Gulf of Mexico, and is capable of taking away all the excess waters. I have seen it stated that a river is spoiled by having an escape like that, but I think that is a misstatement. If a river is carrying 1,500,000 cubic feet a second in flood and a breech occurs on one bank, and 500,000 cubic feet goes away, and that stream, discharging 1,500,000 cubic feet, suddenly finds itself carrying only 1,000,000, the silt is immediately deposited. But if you have a river capable of carrying 1,500,000 cubic feet and it suddenly has 2,000,000 cubic feet put into it, I think it is a wise thing to let that extra 500,000 cubic feet go down the escape and never enter the channel capable of carrying 1,500,000 cubic feet. I am rather rusty in my Latin, and I wish you to correct me if I am wrong, but I think the old Latin phrase is "*Natura non facit saltum*," that is, "Nature makes no leaps." It is not the deliberate removal of water, but the sudden removal by breaches or crevasses which is so harmful.

There is no reservoir that you can find for a river so good as one of these open basins on its banks. The river carries its 1,000,000 cubic feet per second and it is within its banks. As it rises above 1,000,000 it overflows not in one place, but in a hundred or a thousand or a million, along its entire length of bank. That kind of overflow does not disorganize the stream, for it leaves the stream in perfect order and relieves it of all excess of water, so that if you make a levee along one bank of the river and let the other overflow, you get a moderately increased scour under control, and not out of control, as it is if levees are built on both sides. The ancients did this always. They built a levee on one bank, and when the river was capable of passing the excess of water with one levee, they went to work on the other. In this country you have brought both levees up together. If the central government were to say to a State, if you put up your levee where we are not prepared for it we shall give you no help, the State would wait until the levees below were ready, because no one in the valley would move a hand's breadth if they were *sure* that the central authority would give them nothing.

We often hear it stated that things are better to-day than they were in 1882, when there was one of the greatest floods the Mississippi has known, because there were 442 breaches then and only nine in 1912. But when the water was only of a moderate height above the country, hundreds of breaches would not do as much harm as one breach when it is 12 or 15 feet above the level of the country. To compare these many breaches with one large breach is very well explained by a fable of Æsop which nicely expresses this situation. The lioness with her one cub went out for a walk and met the fox with her ten cubs. The fox called attention to the great discrepancy in numbers between her cubs and the lioness'. The lioness replied: "My dear woman, *this* is a lion."

To-day a new difficulty has begun to appear owing to raising the water on the levees up to 10, 12, 14, or 16 feet. These are "boils." Where the water is 5 or 6 feet high on a levee there is no difficulty. But where the water rises, it forces it way through decayed trees buried in the soil under the levees, or through holes bored by crabs, and bursts out on the other side like a geyser. Many breaches in the last overflow they say are attributable to this sudden undermining of the levee which no human being could foresee.

So serious has this become to-day on the Mississippi that Major Dabney, one of the most experienced of the Government engineers in the valley, thinks it may be necessary to build two levees, one behind the other, which will add many millions of dollars to the expense of this work.

I have often heard it said that it seems a pity to allow any land not to be protected by a levee and to leave it open to the floods. But when you consider that out of the 12,500,000 acres in the upper valley, there are only 4,000,000 cultivated to-day and 8,000,000 are still primeval forest, to go ahead and throw up levees to drown out people down below in order to protect a large area of primeval forest is not doing any good to the country, but rather harm. While if the water was allowed to flow over this land, not as it likes, but within dikes carefully done as it is in Egypt, this land in 20 or 30 years would be so much improved that those people whose land was outside the levees would possibly find themselves better off than those who had been inside the levees. In two years out of three they could get first-class crops on unprotected land; and even in bad years a half crop if they wished.

With these propositions, I shall now go to the question of what the ancients would have done if they found themselves in the valley to-day. The first thing I think they would have done, judging from what I have seen in Mesopotamia, they would have protected the salient bends. They would have taken care that there was no more eating away of levees. There is no use putting up a very expensive levee here and there and letting the river eat it away. Little progress can be made in this way. You are always spending your money in repairing. And this point is very well insisted on by the Government engineers and they carry it out to the limit of the growth of the stuff of which the mattresses are made. But more than that might be done now with reinforced concrete at your hand. The stuff of which they make mattresses can only grow at a certain rate, but this reinforced concrete can be made anywhere, and you could keep ahead of the damage that is going on in the valley. The conditions on the lower Mississippi to-day are very serious, and delay may produce a flood which may be not unlike Noah's flood, some day.

All cutoffs would have been allowed by the ancient engineers, according to all their works which I have seen. They would never have spent great sums of money to prevent the river from cutting away inside the channel, because it only takes away money and labor from attending to the main object of keeping the two main levees protected. All money spent inside to keep these bends from cutting across is money thrown away. There is nervousness about this cutting, which is not warranted by anything I have seen. I remember on the Karun River in Persia years ago, the river took an 8-mile curve and came back again to the same point, and you could see it 4 feet higher on one side than on the other. They said whenever that is cut through navigation will be upset for a long time. It cut one day, and within a week the river was flowing in its new channel, and it was difficult to see how it had run around the 8 miles because it seemed to be so happy in this new channel, just as if it had been there from eternity.

The next thing they would do, I think, would be to calculate what the height of a 2,000,000 cubic feet per second flood with 10 per cent added, or 2,200,000 cubic feet per second, would be in the valley, and put up profiles from Cairo down to New Orleans and let everybody see what it meant to have water like that clear down the valley. You have had floods, but you do not yet know what it means to have a very high flood without a breach. This country, it seems to me, has so many problems and big things before it that questions on the lower Mississippi, however serious they may be, are allowed to drift, and yet they reflect on your country, and make it appear just like China, or one of those derelict countries like Mesopotamia.

The next point. Even now though the levees are too long and everybody knows it, the engineers and the government do not prevent the Yazoo and other basins from extending their levees farther south, or the St. Francis basin from extending its levee and making the difficulties greater than they are at present for those people still farther down the river. I have been a government official for twenty-four years under strong central governments, and they say to any one "Lengthen that levee even 1 inch and we will not protect a single inch of it." No more was necessary. No one would dare for a minute to do anything against the will of the government which had all the money in its hands and to whom everybody appeals for help.

Allowing 6 feet above the bank as not a dangerous height, I calculate that we need reservoirs on the Mississippi which represent 34,000,000 acre feet, that is 34,000,000 acres 1 foot in depth, or 1,000,000 acres 34 feet in depth, or something between them. To meet this we have the left-hand small basins and the Yazoo and others open at their ends where we have 6,000,000 acre feet, so we need 28,000,000 acre feet, to be provided by reservoirs. Reservoirs up in the mountains and in the clouds I don't think would affect the Mississippi. They would be so late or so mismanaged that their influence would never reach the place in the nick of time. I am reminded of one of the sayings of Moses to the children of Israel when I hear people saying that if you will only put forests on the hills and put reservoirs up at the heads of the Mississippi River, you will settle the question. This question came up in Moses' time, and he said "Seek not for salvation at the tops of the hills, look not for it at the ends of the valleys, for thy salvation is nigh thee, at thy very doors." We have got the St. Francis basin, far cheaper than any reservoir and one of the cheapest in the world, of which three quarters would suffice for our needs. Let them protect the upper quarter with levees and let three quarters of the basin be allowed to be put under water and it would protect the Mississippi River for 20 or 30 years, until the river had widened its channel. In the meantime, with transverse dikes from the river to the hills, well adjusted and employed like the ancient Egyptians did theirs, you could let the muddy waters of the Mississippi flow over this basin so that the lands would be greatly improved, and when the time came for the owners to enter into possession they would be much richer than they are to-day. If you go across this basin down a range of 40 miles, you see only a few wooden shanties and a little clearing and cultivation, and everything else primeval forest. To protect this primeval forest and put the whole river for hundreds of miles into extraordinary difficulty is foolish. If the people don't like it, the central government could buy this land. If you make reservoirs in the hills, you will have to buy the land which is to be covered and you will put that out of cultivation forever; while using this basin, far from putting it out of cultivation forever, you would after 20 or 30 years make it many times as rich as it is to-day, and if the central government purchased it, they could afterward sell it at a handsome profit.

Nature has succeeded very well in all her efforts because she has a law. It has been well expressed in the lines "So careless of the single life, so careful of the type." In the Mississippi Valley you see that everywhere the action of this country has been "So careful of the single life, so careless of the type," and unless a return is made to Nature's wise law no permanent improvement can be assured.

I have already spoken of forests, so I need to say little here. There are a few people who have planted oaks, chestnuts, and other fruit-bearing trees on a few acres of land that belong to them and have made money. This is far from saying that every single man who has a square mile of hillside in the country will go at once and plant trees. Ninety-nine out of 100 people are lazy, and they are not going to plant the hillsides with trees. So Uncle Sam, the kindest-hearted man that ever was known, is called on to plant the forests. Those forests, scores or hundreds of years hence, will help the stream in low supply and ordinary floods, but they will have no effect upon it in the heaviest floods, and these are the floods we are concerned with.

If you build reservoirs up in the hills or build a dam across the valley, you must first have expensive openings in it so that the waters may traverse it in order that it may be empty when it is needed. If it is full of water when the rain comes it will be useless. So that these reservoirs that are provided for flood protection cannot be used for supplying power or helping navigation.

And moreover, what is the use of protecting 19,000,000 acres in the Mississippi Valley with levees, when only some 4,000,000 are cultivated and the rest is primeval forest, and there is neither population nor money to reclaim it.

The people of the Mississippi Valley for many and many a year have been rightly nervous, and advantage

is being taken of this nervousness, for everyone with a panacea to go shouting that something must be done at once. Now there is a very well-known saying of Lord Palmerston's: "Where you hear a number of people saying that something must be done, something must be done at once, you may be quite sure something very foolish will be done."

I have spoken of the Mississippi. I now come to Pittsburgh. We have here the same problem as on the Mississippi, but in a smaller way. The only difference is that on the Mississippi the man on the right bank worries because the man on the left bank puts up a levee. Here you have the satisfaction of knowing that you have created your own difficulties. You have two rivers, the Allegheny and Monongahela, with only 20,000 square miles drainage basin, which really is not a big thing. It is the first small thing I have seen in America. Your rivers are quite ordinary rivers, but they have for short intervals of time most extraordinary floods. The maximum floods they carry are just about what the Tigris and Euphrates carry when they meet. Those rivers have it for months and you have it only for a few hours. But a few hours of water flowing through your house is almost as big a worry as having it for a week.

These two rivers as they come down do not have big reservoirs as the Mississippi has lower down, but they had very fine reservoirs at one time. First of all there were the overflows in the valleys themselves. Then going back in every direction were the side valleys, wide in places and narrow in others. With a river that comes down in high flood for months they would have been of no use, but with a river that comes down only for a few hours or days, the valleys gave ample elbow room, and by the time the flood got down to the Ohio River, all its force had been spent in filling up these side openings and before it had time to fill them all full the storm had ceased and the flood had passed.

Now what have you done in these years? You have deprived the river of all elbow room. I saw a bridge where the river was 1,300 feet wide, and to-day it is only 650 feet. Nearly half the river has been filled up with factories, with railroads, and with every kind of industrial institution. Then you have erected numerous bridges not with piers one in front of the other, but all irritating the river and holding up the water in every way they can. Now when the river comes, instead of having elbow room as is had in the old days, it finds itself contracted within two solid walls. And if you calculate the height it has come up above the old floods, you will find it has made up in height for the area you yourselves have taken away from it on both sides.

I have heard it said that railroads and factories join in these petitions to Uncle Sam to help them out of their difficulties with reservoirs. The only thing I have been able to compare it to was a case that happened in Europe some years ago. A boy of nineteen murdered his father and mother, and when he was up for sentence the judge asked him if he could mention any extenuating circumstances, he said "I appeal as a poor orphan." These people are very different from those poor people who live in houses that used to be above the flood and now find the water flowing through their drawing-rooms when they least expect it.

As far as I can see, you have no more difficult problem here than the city of Rome had where in the course of years the Tiber had risen 10 feet above the Aventine quarter. They spent many millions of money, but they bought all the houses on one side of the river and widened the channel about a third wider than it was, built two walls and raised the banks, and now the whole town is protected. It cost a great deal of money, but they had no one to appeal to but themselves to do it, and they did it. In Pittsburgh, too, a wall has been proposed. I speak under correction, but when I see the shingle and stuff on which you are founded I think a wall would not prevent water from coming up from underneath; but it would be easy to raise the streets on both sides of the river and then when the flood came it should not get across it, and whatever water seeped through into cellars might be pumped out over the banks. Whether reservoirs are made or whether they are not made, I think this street raising ought to be made on both sides straight away like Rome. If you do make reservoirs and you have a basin of 20,000 square miles, and your reservoirs cut off the water of 10,000 square miles, you still have 10,000 square miles this side of the reservoirs, and if you have a heavy downfall of rain on that, it might bring down quite enough to worry you, especially if you had warm rain on top of snow. I think reservoirs ought to be made if they can be made, but whether they are or not the streets should be raised by earth, and if every foot of earth you used were taken from the river you would improve the river to that extent.

The factories and railroads, built low down near the river, must be raised on their own base. I do not know the cost of raising them or whether it is worth while to do it, but considering the millions of dollars they lose owing to the floods, it should be worth doing. No reservoirs in the world could lower the water sufficiently to keep the floods out of them.

For navigation as I see it, there is no better plan than you have, with your weirs and locks, but you have an acid water which eats iron in an extraordinary way and any kind of permanent weir which would not necessitate these iron structures that raise it temporarily would be a great gain. This point was brought to my attention by Capt. Fiske. He said, "Why couldn't they make bars across the river in places so as to have sufficient length to have no movable apparatus in it and make them of such height that it would suit low water and floods would pass safely over?" This is certainly the correct way for this kind of work, and I had the advice of some of the best men in India when I proposed it for the Tigris. There are many places on your rivers where you could build permanent weirs of a height to suit low-water navigation and the high-water would flow over very freely. On the Nile we built permanent structures 9 feet above bed level of the stream, which hold up 9 feet of water in the summer time, and when the floods come you would not know there was anything in the river at all, because when the river rises 30 feet a 9-foot obstruction does not count for anything.

Still in an important city like Pittsburgh in addition to whatever you do, something in the way of reservoirs ought to be done if it can be done. In a recent book which you have written on this reservoir question I see that the quantity of water you consider necessary to impound in these reservoirs seems to be in excess of what you need. In all the calculations it has been assumed that when the river rises, its discharge increases up to its maximum gage. As a matter of fact, it does just the opposite. When it is rising fast, it has a great velocity and a great discharge, but when it comes to within 7 or 8 feet of the top, the velocity has begun to decrease and with it the discharge. On the Tigris, which jumps up and down very much like this, when the river gage is 15 feet rising, the discharge is 180,000 cubic feet a second. When it has risen to 20 feet and reached its maximum for that rise, its discharge is 120,000, and when it has come down on the other side to 15 feet the discharge is 90,000 cubic feet per second. As in all these estimates, you have allowed for an increasing discharge, and not reduced by half for the falling gage, a much smaller quantity of water than you have assumed would, I think, suffice to shelter you from these hours of high flood which produce all the worry.

The difficulty here, I think, is that the same operation which made your soil very rich in coal has made it very bad for reservoirs. This horizontal sandstone you have here and shale in alternating strata is considered the worst foundation for reservoirs of anything in the world. More accidents to big reservoirs have happened on it than any other. If the strata are inclined at a steep angle, and you build your dam on it, it rests on the hard particles, and the weak strata are more or less ignored. But if you have horizontal strata and you hold up water with a 150-foot head, the water works its way through the shale and gradually undermines it; because horizontally it can do it very easily, and when it reaches a certain point the upper strata settle and the dam collapses.

In your book you show that you spent money on many things, but not one penny to find out what your foundations are, and all the rest of it is worth nothing until you are sure of your foundation. You ought to spend some $10,000 for drills and take two of the nearest sites and expose the foundation and see if you can build a dam there. If you find really good foundation, your difficulties will be at an end. There are many sites in Algeria where the French government would give anything to be able to build a reservoir on soil like this. In despair they did build one, but in a few years it was swept away. And your condition is such that if you had a high flood and a reservoir with 150 feet head on the hills above you and it happened to breach and came on the top of the flood, all the disasters you know of to-day would be but child's play. And if you had two in the same valley and the upper one burst and came down on the lower one, and the two came together, you might open the early chapters of Genesis and begin reading about Noah's flood to comfort you. So of all the things that are necessary the first is to be sure. Reservoirs with good foundations up in the clouds are no use. Even if you could open and shut them it would be too slow coming on its way. They must be low down. I never saw such bad-looking stuff for reservoirs, and I found that no one had bored down one foot to see. For when you have bad rock it is often necessary to go down 50 or 100 feet, and when the water flows through the dam you have got to make an apron down stream 100 yards wide in order to protect the rock from the action of the water. You have two expenses, one a very expensive dam and the other a very expensive floor down stream to prevent it from being undermined. As far as reservoirs are concerned, if you had granite or steeply inclined crystallized limestone of any of the good rocks in which reservoirs are built, I would back your reservoir project against all the others. If ever the central government pays for the reservoirs, it would be your certain duty in this town if a reservoir were built near here, to see that the foundation were good. Because rivers with rock suitable for foundation have been controlled, it does not necessarily follow that you can do the same if you have no suitable rock. You read in the Acts of the Apostles that the seven sons of one Sceva, a Jew, saw St. Paul casting out a devil, so they thought they could, but the man possessed of the devil leaped upon them and left them wounded and half dead. You see their faith was not well founded.

If the reservoirs can be made, or if they cannot, the duty of raising the streets on both sides sufficiently high to protect the lower paths of the town is incumbent on you.

A Remedy for Beri-Beri has been discovered, according to the last annual administrative report of the Federated Malay States. Pending a thorough investigation by the medical research institute of the colony, the details of the remedy are not announced.

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